THE UNIVERSITY OF ALBERTA

THE EFFECT OF CIRCUIT TRAINING AND ISOMETRIC EXERCISES ON TREADMILL PERFORMANCE

A THESIS

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ABSTRACT

Three groups of eleven first year male students at The University of Alberta participated in the study. The subjects were initially equated on the basis of performance time on the Balke Treadmill Test. All three groups attended the required physical education classes twice per week for five weeks in which badminton was the activity. In addition to badminton, Group I did circuit training and Group II did isometric exercises three times per week. Group III acted as a control group. Groups I and II did two work outs a week during the last ten minutes of each class period while Group III continued playing badminton. In addition to class times, Groups I and II met once per week for ten minutes.

The mean increases in treadmill performance times of all three groups were statistically significant at the .01 level of confidence. The mean improvement in the circuit training group was 2.95 minutes ($t=5.36$). The mean improvement of the isometric group was 1.28 minutes ($t=3.30$), and that of the control group was 1.73 minutes ($t=4.59$). There was no statistically significant difference between means of the circuit training group and the control group ($t=1.64$). Similarly there was no statistically significant difference between means of the isometric group and the control group ($t=.78$). The difference between means of the circuit training group and isometric exercise group was statistically significant at the .05 level of confidence ($t=2.42$).

Within the limitations of the study it was concluded first, that ten minutes of circuit training or ten minutes of isometric exercises in addition to badminton, three times weekly, are no more effective in improving treadmill performance time than is badminton alone. Second, circuit training, as used in this study, causes a significantly greater improvement in treadmill performance than do isometric exercises.

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STATEMENT OF THE PROBLEM

Introduction

Recently, exercise programs have come forth which propose to improve certain aspects of fitness with short term work outs. Among these programs are isometric exercises and the 5BX program. Perhaps these programs have come about as the result of an attempt to meet the physical needs of todays society. Men burdened with the pressures of modern business life often do not have sufficient time to keep their bodies fit by prolonged exercise programs.

In attempting to assess the value of short term exercise programs in the development of physical fitness there are at least two problems. The first is a clear definition of physical fitness, and the second is adequate measurement of the variables of physical fitness. It is not the purpose of this study to completely resolve these problems. This would require much research over a number of years. Fitness will here be measured in terms of a cardio-respiratory response to exercise.

Balke (1:74) says the determining factors of physical fitness are the size of the physical reserves of the individual and his general adaptability to great physical demands. He calls this the individual's biodynamic potential, which is composed of functional and metabolic potential. According to Balke, "The best test of physical fitness would be man's ability to survive under extraordinary biological

demands" (1:74). Hettinger, et al. (2:153) and Astrand (3:324) have limited the definition of physical fitness in their studies to the capacity of the individual for prolonged heavy work.

Balke (1:74), attempting to assess physical fitness, has developed a successful technique for measuring the cardio-respiratory aspect of physical fitness. The method involves determining man's aerobic capacity for maximum functional demands. The exercise consists of walking up-hill on a treadmill by increasing its slope one percent per minute. The speed of the treadmill is kept constant at 3.4 m.p.h. Performance is measured by the length of time it takes the pulse rate of the subject to reach 180 beats per minute.

With this measure of work capacity available, it was decided to investigate the effect of certain of these short term exercise programs on the ability of the body to adapt to increasing work loads. The two types of exercises studied were selected programs of isometric exercises and circuit training.

The Problem

It was the purpose of this study to investigate the effects of five weeks of a selected isometric exercise program and five weeks of a selected circuit training program on treadmill performance as measured by the Balke treadmill walking test.

Subsidiary Problems

The sub-problems of this study were to investigate the effects of five weeks of an isometric exercise training program and five weeks of a circuit training program on:

1. Pre-exercise standing heart rate.
2. Pre-exercise oxygen consumption.
3. Heart rate during five minutes of recovery from exercise.
4. Oxygen consumption during three minutes of recovery from exercise.

In the problem the null hypothesis asserts that the means of the treadmill performance times of the three treatments will differ only through fluctuations of sampling. The treatments are circuit training, isometric exercises, and a control activity.

The alternate hypothesis asserts that the means of the treadmill performance times of the three treatments will differ as a result of the experimental procedures carried out.

Importance of the Study

The work of Hettinger and Muller (4) has stimulated investigators to study the effects of isometric exercises on strength (6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17), and muscular endurance (18, 19, 20, 21, 22, 23). Many of these studies have been reviewed by Lawther (7) and Hettinger (19). However, few studies have been done on the effects of isometric exercises on circulorespiratory endurance. Similarly, circuit

training has been studied with respect to strength development, but not to any degree with respect to the physiological aspects of circulation and respiration.

Circuit training, although extensively used in England, is not well known in America. It would seem that this program should be used more extensively in our school systems because it can be adapted to varying school situations. Also it is "...consistent with current educational philosophy, in that each child is permitted to develop towards his maximum capacities at his own rate" (5:12).

It is important, therefore, that these two relatively new concepts in physical activity be investigated further. Since circulorespiratory endurance is a desired outcome of most forms of training, it is worthwhile that isometric exercise training and circuit training be evaluated from this viewpoint.

The importance of the study, therefore, is that it attempts to provide some evidence about the effects of circuit training and isometric exercises on performance on a treadmill test, which depends primarily on circulo-respiratory endurance.

Limitations of the Study

1. The study is limited to 45 male university students and to a period of only 8 weeks.
2. The students are only those registered in the required physical education program and are, therefore, all first year university students.
3. Only one component of physical fitness is considered

(24:78). This is the cardio-respiratory aspect of fitness.

4. In determining oxygen consumption, a measure of carbon dioxide production was not determined, and the respiratory quotient was assumed to be unity.
5. The laboratory environment was not constant throughout the testing; temperature and humidity varied from day to day.
6. Only one form of circuit training and one group of isometric exercises were studied. It is conceivable that other forms of circuit training or isometric exercises would have different effects.

Definition of Terms

Isometric exercise. Isometric exercise refers to isometric contractions (static contractions) in which the muscle length theoretically does not change. Technically no work is done but heat is given off as energy. The muscle develops tension which is insufficient to move body parts.

Circuit training. Circuit training is a system of exercises arranged in the form of a circuit in such a manner as to enable a large number of students to proceed from one exercise to another without undue local fatique, and at the individual's work capacity (5:12). Progression on a circuit is measured, initially, by decreasing time of performance, and secondly, by increasing loads or repetitions (5:12).

<u>Circulo-respiratory endurance</u>. Circulo-respiratory endurance is defined as the ability to sustain prolonged activity in which circulo-respiratory mechanisms are the primary limiting factors (24:607). In activities which involve prolonged action of large muscle groups, it is circulo-respiratory efficiency which will delay the onset of fatique.

<u>Muscular endurance</u>. Muscular endurance is "The capacity of the individual for continuous performance of relatively heavy localized activity. It makes small demands on the functions of respiration and circulation before local exhaustion sets in. It depends to a large extent on strength, but also on the efficiency of the blood supply in the muscles involved and the viscosity of the muscle tissue". (13:17).

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CHAPTER II

REVIEW OF THE LITERATURE

There have been numerous studies reported on the effect of exercise on the circulo-respiratory systems. However, there is little research on the effects of isometric exercises and circuit training on the circulation and the respiration. This review will attempt to summarize the work that has been done in these areas and to consider information relevant to the study.

Literature Pertaining to Isometric Contractions

Steinhaus (1:4) has reported and summarised the main initial findings of Hettinger and Muller on isometric exercise. They are as follows (1:6):

1. Muscle strength increases an average of 5% per week when the training load is as little as 1/3, or even less, of maximal strength.

2. Muscle strength increases more rapidly with increasing intensity of training load up to about 2/3 of maximal strength. Beyond this, increase in training load has no further effect.

3. One practice period per day in which the tension was held for six seconds resulted in as much increase in strength as longer periods (up to full exhaustion in 45 seconds) and more frequent practices (up to 7 per day).

4. The cause of the increase in strength (training stimulus) is believed to be neither the intensity of contraction nor the degree of exhaustion of a muscle fiber, but rather a condition in which the oxygen supply to a muscle fiber ceases to be enough for its need. A further oxygen deficit is not a stronger or more effective stimulus. Thus, they postulate an 'all or none' characteristic of the training stimulus to hypertrophy. The observation that strength grows more rapidly as the training load increases from about 1/3 to 2/3 maximal strength is only an apparent contra-

diction. They believe that due to the internal arrangement of fibers within a muscle not all fibers are equally taxed so that until the load is about 2/3 maximum are all fibers suffering some oxygen deficit...

5. The rate of increase in strength sometimes varied considerably in the same person when two comparable training periods separated by a long rest period were compared.

6. There is a ceiling on the development of strength in every muscle. Attainment of this maximum is usually accompanied by pain resulting from some injury within the muscle that stops further increase in effort.

7. Maximal strength of any muscle in the body is probably about 3 times the tension demanded of it in everyday activities...

8. Under the training regime already described the average increase in muscle strength is about 5% per week. If training is discontinued after a few weeks, strength recedes at a loss of about 5% per week back to the original value.

9. A muscle trained to be, let us say, 50% stronger than originally may thereafter be maintained indefinitely at this level by two, probably only one, maximal contraction effort per week...

10. When a muscle that has been trained to 50% greater strength was maintained at this level for 12 weeks by one maximal contraction per week and then given no further training nor testing the results were astonishing. In the first 12 weeks of no special activity, strength was almost completely retained at the high level and in the next following 28 weeks... strength was still far from having returned to the level it started from at the beginning of the experiment.

Hettinger (2:75) has reported the results of many more recent studies in a new publication, Physiology of Strength. He has summarized the findings as follows:

1. It has been shown that muscle tension, i.e. the training strength, seems to be the important point in muscle training.

2. The minimum training stimulus in muscle tension is about 1/3 of the maximum strength obtainable in voluntary isometric muscle contraction, and an exertion of 40 to 50% of the current maximum strength of the muscle gives the muscle the maximum obtainable training effect.

3. It is unnecessary to keep up this tension to the point of complete fatique of the muscle to get the maximum in training effect. A period representing 10 to 20 percent of the time it takes to reach complete fatique of the muscle - which prevents further holding of muscle tension - is enough to reach the maximum obtainable training effect.

4. One single training stimulus per day is adequate for the maximum obtainable training effect for a certain muscle group, in a certain individual, during a certain time.

For practical purposes, in order to train the muscle for increasing strength, we suggest exercising the muscle group which is to be trained by making one isometric maximum muscle contraction against a resistance each day...

It was shown that after a training period the strength gained during the period decreased at a speed which was about one-third of the speed at which it had increased during training.

Further it was demonstrated that after a training period a small part of the total increased strength remained indefinitely, which means that 'normal strength' was raised that amount by each training period.

The increased strength gained during a training period can be maintained by giving training stimuli every fourteen days.

In the area of the circulo-respiratory effects of isometric exercises there are a limited number of studies. This is surprising because the work of Hettinger and Muller hypothesised that the training stimulus in isometric contractions was a state of hypoxia produced in the contracted muscle

during exertion. This is a state in which the oxygen supply to the muscle fibers is not enough for its needs (1:4). Morehouse (3:197) says that this theory cannot be supported on the basis of experiments done at the University of California by O'Connell.

Studies that have investigated the effect of occluded circulation on strength development have generally concluded that occlusion does not increase strength (3:206). Clarke (4:3) hypothesized that since the blood flow through the muscle during tension was occluded that much of the energy cost of a contraction, if maintained for very long, would have to be paid off in the form of oxygen debt after the muscle was relaxed. To test this hypothesis, subjects held 50, 35, and 20 pound weights on the knees which were partially flexed. Rather sizable oxygen requirements and oxygen debts were obtained. Those seemed to increase linearly as the size of the weight increased. When compared with available data on dynamic work of equivalent metabolic cost, the results showed significantly smaller oxygen income and larger oxygen debt for the static exercise. These findings support the theory that the local circulation was being occluded by the muscle tension during this type of exercise.

Grant (43) studied the effects of isometric grip contraction on vascular changes. He concluded that a maximal contraction compresses the blood vessels. There was an increase of blood flow after exercise and the longer and more

stenuous the exercise, the greater was subsequent hyperaemia. Anrep and von Sallfield (44) and Barcroft and Millen (45) support these findings.

The research that has been done on the effects of isometric contractions on blood pressure and heart rate indicate that these functions are increased, but to a lesser extent than in dynamic work (3:197). Tuttle and Howorth (5:294), using isometric contractions of 1 minute duration on a grip dynamometer, found that at the end of 15 seconds of static work, pulse rate, systolic pressure and diastolic pressure were significantly greater than at rest (5:295). During the remainder of the work period no further changes in pulse were found, but the systolic and diastolic blood pressure showed a gradual rise. Ten seconds after the cessation of work the pulse rate was not significantly different from the resting level. The systolic and diastolic blood pressure was still significantly greater than at rest but sixty seconds after work these pressures were not significantly different from the resting level. It was also found in this study that during isometric work a steady state or a very small oxygen debt was maintained.

Thompson (6), in comparing the effects of isometric and isotonic work on blood pressure, found that isometric work caused a sharp rise in both sytolic and diastolic blood pressures. The diastolic blood pressure returned to the resting level within 30 seconds after work ceased. The isometric work consisted of squeezing a grip dynamometer at a maximum

effort for one minute. Blood pressure was recored in the inactive arm. In contrast to isometric work, a moderate bout of isotonic work (one minute of peddling a bicycle ergometer where 1250 kgm. of work was done) caused no signficant change in diastolic pressure. It did raise systolic pressure. Thompson reported further that experiments conducted have shown that four times as much oxygen was required to do the isotonic work as was used in doing the isometric work.

Some isometric exercise programs have been shown to develop muscular endurance (7,8,9). Swegan (7) defined endurance as the ability to persist in elbow flexion at a predetermined rate, and cardio-vascular endurance as the ability to ride an ergometer at a predetermined rate and resistance. Two groups were equated initially on muscular endurance, speed of movement, and cardiovascular endurance. Group A did progressive resistance training (weight lifting up to 10 repetitions) and Group B did static contractions for 6 seconds at 2/3 maximum. The exercises were done 3 times per week for 10 weeks. The findings were that muscular endurance was increased significantly by each method. The static contraction group improved significantly more in left elbow flexion only. There was no significance between groups. Static contraction methods seemed to be more effective for developing endurance in knee extension, than knee bends (cardiovascular endurance as measured by work on the bicycle ergometer).

Baer (8), training the wrist flexors with isometric

contraction exercises of 2/3 maximal strength, produced large increases in work capacity of the wrist flexors.

These results are a bit surprising because as Dennison et al. (9:348) said, "...one would assume that muscular endurance dependent partially upon the efficiency of capillary circulation would not be significantly improved by a program of static training", since vascularization is not markedly improved by isometric exercises. Similarly, one would assume that endurance which depends primarily on ventilation and circulation would not be imoroved significantly by isometric exercise. Steinhaus and Karpovich have cited opinions on this subject (10:21). Steinhaus (10:21) has stated that isometric exercises do nothing for the heart or lunqs, and Karpovich (10:21) said that isometric contractions will not build up endurance and stamina. Muller (11: 41) supoorts these statements.

Most of the studies on isometric training programs have used only one muscle group, i.e. quadriceps or wrist flexors, and have used one contraction per day, held at 2/3 maximal for 6 seconds. However there have been a number that have studied the effects of multiple repetitions of the same exercise (12, 13, 14, 15, 16). These studies have used from as little as 3 maximal isometric contractions per day, to as many as 30 maximal contractions at one minute intervals per day. Taylor (17) has also comoared the effects of 12 second contractions versus 6 second contractions. The general findings are that some investigators find significant differences in

strength using a single 6 second maximal isometric contraction per day five days a week. Others do not, but say that significant differences in strength and muscular endurance are brought about by multiple maximal contractions of 6 second duration, or single maximal contractions held for longer than 6 seconds (12, 13, 15, 16, 17).

Literature Pertaining to Circuit Training

Morgan and Adamson (18) have done the initial work concerning the development of circuit training in England. Circuit training as a progressive resistance activity has proven to be popular and successful in the United Kingdom (19:12).

Howell and Morford (19:12) have reported that:

> Circuit training evolved over the years out of a search for a method of fitness training that would appeal to students and would, at the same time, progressively develop muscular and circulo-respiratory condition. The latter can only be achieved by exercising with progressively heavier loads at a progressively increasing work rate. Specifically, circuit training aims to increase circulo-respiratory endurance, muscular strength, muscular endurance and muscular power.

There are several different kinds of circuit training programs. Any number of combinations of exercises have been used. Some have used weight training exercises to compose the circuit and others have used combinations of both weight training exercises and calisthenic exercises. No matter what exercises are used to compose the circuit, circuit training attempts to increase strength by the overload principle. Circuit training uses three training variables, load, repet-

itions and/or time.

Taylor (21) has studied the effects of circuit training upon the cardio-vascular and muscular status of business men. He equated 42 business men into two experimental groups. One group did a program of calisthenics, the other a circuit training program. A third group was used as a control. All the subjects were tested initially in the items of the Larson Muscular Strength Test and the Harvard Step Test and again at the end of an eight week experimental period.

Both experimental groups showed gains in performance that were statistically significant for the cardiovascular and muscular strength test. There were no statistically significant differences between the means of improvement of the two experimental groups. It was concluded that both the calisthenics and the circuit training programs, as used in the study, were effective methods of improving the cardiovascular and muscular status of business men.

Brown (22) studied two groups of grade 5 girls. One group (experimental) participated in a ten-minute circuit training program at the beginning of each lesson for 8 weeks. The remainder of the lesson consisted of the regular physical education program. The second group (control) participated in only the regular physical education program for 8 weeks. The groups were tested initially and finally on the AAHPER Youth Fitness Test.

Both groups made statistically significant gains in

the total physical fitness scores. However, there was no statistically significant difference between these mean gains. The findinas of Watt (46) support these findings. He concluded that significant gains in ohysical fitness level as measured by Carter's revision of Rogers' Physical Fitness Index Test can be achieved by low fitness students by taking oart in circuit training.

Nunney (20:188), on studying the effects of circuit training on various swimming items (endurance, speed, weight and strenqth of swimmers) during a 6 week training period, concluded that there was no significant evidence to show that circuit training, which included weight training exercises, was in any way detrimental to swimming performance.

Literature Pertaining to Treadmill Performance as a Test

Durnin et al. (23:164) said, "...the physical condition before training can be deduced, at least in part, by the reactions of a group of subjects to a standardized exercise prior to training, and there is little reason why the intensity of the training cannot occasionally be controlled and defined". They also said (23:164) that, "The exercise test should involve large groups of muscles and should be simple to do, the efficiency of the subjects should be high, and the work should be measurable". Also the indication is that the test should be a submaximal one (23:164). Astrand (24:325) said that the treadmill or the bicycle ergometer is satisfactory for testing submaximal work intensity. He went on to say that several methods are

unsatisfactory, i.e., (1) heart rate at rest and after light work of short duration, (2) recovery rate determination, and (3) all out, or maximal test work. A test based on gradually increased work intensity, said Astrand (24:325) is satisfactory provided: (1) the increase is not too sudden, and (2) maximal stress is determined by the work load when a given pulse rate is reached.

The treadmill performance test used in this study will be based on the work of Balke <u>et al</u>. (25, 26, 27). This test provided a work stimulus that could be increased gradually. Also the treadmill has several other advantages.

Taylor (28:132) said that, "...the skill, (mechanical efficiency) of walking on either the level or on a grade on the motor driven treadmill is remarkably constant from one individual to another", also Erickson <u>et al</u>. (29:400) concluded, first, that there is little training effect as a result of practice. The oxygen consumption measured the second time a man is on the treadmill gives a valid figure which will not be influenced by an increase in the experience of the subject in walking on the treadmill. Second, the small intrinsic variations imply good reproducibility and third, comparatively small variations of speed and grade produce accurately measurable differences of energy expenditure. With regard to the training effect or learning effect, Billings <u>et al</u>.(30:1006) said that:

> Analysis of variance demonstrated no significant difference between any pair of sessions other than the second and first. Since the incremental effect was as

pronounced when 3 weeks elapsed between sessions 1 and 2 as when sessions were conducted at one week intervals, it was concluded that the increment probably represented a learning effect rather than physical conditioning.

The progressive treadmill exercise test described by Balke (25:74) and used to determine biodynamic potential was essentially as follows:

> Stress is gradually increased by elevating the slope in minute intervals. Thus, during walking at a constant speed of 3.4 m.p.h., the energy demands are gradually increased. These demands are met by proper adjustments of the cardio-respiratory systems: the increase in heart rate and in pulse pressure indicates the enlargement of the cardiac output, which is of primary importance for adequate oxygen and energy supply. The progressive demands on the respiratory system, handling the metabolic gas exchange, are expressed by the increase on pulmonary ventilation.

The subjects started walking on the horizontal. Each minute the slope of the treadmill was increased 1 percent until the work load was such that the heart rate of the subject was 180 beats per minute. Balke's observations were that 180 beats per minute was the point of "...impending exhaustion" (30:1003). Functional limitations become apparent at this frequency, as was reflected by a decrease of pulse pressure and a decrease in the oxygen supply necessary to satisfy the requirements of the work load. The reason for this, said Balke (25:75), is that at 180 beats per minute the time for sufficient ventricle filling between contractions becomes too short.

A continuation of work beyond this point is, in most instances, not paralleled by further adequate functional adaptation. Work, then, becomes increasingly anaerobic. Balke

points out in another study (48:235) that:

> The point where the respiratory exchange ratio becomes greater than unity can be taken as an indication of impending limitations in aerobic metabolism. The abrupt decline in alveolar carbon dioxide tension associated with a rise in the ventilation equivalent strongly suggests the accumulation of acid metabolites in the blood stream at this time.
>
> An attempt to correlate these findings with significant circulatory events during the final minutes of the test revealed that on the average the respiratory exchange ratio reached unity and the oxygen pulse attained its maximum value in coincidence with a heart rate of 180/min.

The coefficients of correlation obtained were 0.85 between time to reach 180 beats/min. and respiratory exchange ratio, and 0.9 between time to reach 180 beats/min. and oxygen pulse.

These findings are supported by the work of Nagle and Bedecki (49) who conclude:

> 1. The 180 heart rate time in exercise constitutes a valid test of circulo-respiratory capacity.
>
> 2. The 180 heart rate is related to manifestations of physiological incompetence and this can be demonstrated within an intensity range in the exercise stress.

Billings <u>et al</u>. (30:1003) supports this point of impending exhaustion and the fact that heart rate adaptation to each new level of exercise was complete within one minute. They used the method, as did Balke, to estimate maximum aerobic capacity. They concluded (30:1004) "...that the accurate recording of heart rate changes alone can provide a reasonably accurate approximation of the work capacity as measured by this

procedure, without the use of apparatus other than a treadmill, an electro-cardiogram, and a stopwatch".

Work Capacity and Fitness

If the definition of fitness is taken to be the capactiy of the individual for prolonged heavy work, as Astrand (13:324) and others (25:74, 31:153) take it to be, then the treadmill performance test may be thought of in terms of a fitness test. The test as such depends primarily on the fitness of the respiratory and circulatory systems and these systems are the limiting factors of the test as a fitness test.

Despite many limitations on the use of heart rate as a measure of circulatory response to exercise, it is frequently used as an indicator of fitness (32, 33, 34, 35 36, 37). However, the relationship between the heart rate before and during exercise, and rates at varying times after cessation of exercise, in different states of fitness, is not clear. Elbel and Holmer (38:326) said that the coefficient of correlation between the pre-exercise pulse rate and the time required for the post exercise pulse to return to the pre-exercise level was insignificant. Similarly body weight was not related to the amount of time required for the return of the pulse rate to the pre-exercise rate. Also the pre-exercise pulse rate and the increase due to a 2 minute period of exercise was not related. Billings et al. (30:1004) reported that there is no relationship between ability to work to exhaustion and the rate of

recovery in heart rate. They said that the major difficulty in exercise tests involving a fixed work load has been the fact that a level of work which is light for athletes may be maximal or exhausting for sedentary subjects. It appears that pulse rates during recovery from exercise may be of some value in ranking subjects exposed to light or moderate work loads.

Astrand (24:324), in discussing measures of fitness, said that it seems almost certain that if the aim is to examine the physical work capacity of an individual the examination should be made during muscular work. This is supported by Billings <u>et al</u>. (30:1005).

<u>Oxygen Consumption</u>

There have been numerous studies concerning the metabolic cost of exercise using oxygen consumption determinations. These have been reviewed by Karpovich (39:93). However, little work has been done on the effect of training on oxygen consumption during a standard work test. Karpovich reported that oxygen intake during a ski run increased by 2.4 liters, as the result of training (39:121). Balke and Clark (26:84) found that 8 to 12 weeks of training resulted in augmented oxygen intake and in an increase of the maximum breathing capacity during work. Freedman <u>et al</u>. (40:43) said, "Our results suggest that the reserve source of oxygen carried in the venous blood is called upon more and more until exercise capacity is reached, both in the trained and untrained athlete, and probably in normal individuals as well". Stewart and Watson

(41:40) in comparing the oxygen consumption of athletes and non-athletes in the basal state, reported that there is no significant difference between these two groups of college men. In fact, they found no significant difference in heart rate between the two groups in this basal state (41:40). This implies that there is a difference in measurements made during basal state and so-called resting state.

Nagle and Irwin (42:607) have studied the effects of two systems of weight training on circulo-respiratory endurance. Two experimental groups and one control group were tested doing moderate and all-out exercise on a bicycle ergometer. Cardiovascular and respiratory responses were measured, among them, oxygen consumption. An eight week training week training period followed. One experimental group used a system of low repetition and high resistance exercises while the other weight training group used a system of high repetition - low resistance exercises. Both groups used the same series of 13 exercises.

The results showed that no significant changes occurred for the measurements of the minute volume or respiration, carbon dioxide production, oxygen consumption, respiratory exchange ratio, and ventilatory efficiency. It was concluded that (42:614) "...weight training has no significant effects on certain physiological responses to exercise or on circulo-respiratory endurance to which these responses are related".

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CHAPTER III

PROCEDURE

The data for this study were secured from 45 volunteer male subjects attending Physical Education service courses at the University of Alberta during the Fall Term of 1962. The subjects were enrolled in three different sections which met twice per week for 35 minutes.

The progression of the experiment was:

1. Preliminary treadmill trial.
2. Initial treadmill test one week later.
3. Training period for five weeks.
4. Final treadmill test.

Preliminary Treadmill Trial

The purpose of the preliminary trial on the treadmill was to acquaint the students with walking on the treadmill and with the procedure to be followed during the study. Although walking is a normal activity, some aporehension is associated with walking on the treadmill for the first time which reduces the performance time on the treadmill. This was demonstrated in the 5BX studies conducted at the University of Alberta Hospital by Alexander *et al.* (1:21). Erickson *et al.* (2:393) have stated that the oxygen consumption measured the second time a subject is on the treadmill gives a valid figure which will not be influenced by an increase in the experience of the subject in walking on the treadmill.

The preliminary trial was conducted as follows.

The subjects came to the laboratory dressed in a gym suit. They were familiarized with the test by a 3 minute warm-up walk on the treadmill. The treadmill was started in the horizontal position and the speed was 3.4 m.p.h.

After the warm-up, a rest of five minutes was given. During this period, the procedure for the rest of the test was outlined. The subject's height, weight and age were obtained during this period. Also, the skin electrodes used in recording the heart rate were attached to the subject. At the end of the five minutes the subject stood on the treadmill and the electrode leads were connected to the Sandborn Twin-Viso Recorder[1]. The leads were taken from the forehead and from two points on the chest immediately below the nipples. These points were used in the treadmill test administered to the subjects in a study by Alexander <u>et al</u>. (1). These points were selected because of the limited movement of the electrodes and minimum interference with swinging of the arms during treadmill walking. The heart rate was calculated from the record of the electrocardiogram obtained by this method.

Immediately prior to the test, pre-exercise heart rate was recorded, and expired air was collected for two minutes with the subject standing on the treadmill. The treadmill was then started on a level grade and at a rate of 3.4 m.p.h. This speed remained constant throughout the testing. The slope of the treadmill was increased 1 percent per minute

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[1]Model 60-1300. Cambridge Mass.

until the heart rate of the subject reached 180 beats per minute. With this procedure performance time and treadmill grade were numerically the same.

Performance time (corresponding to 180 beats per minute at peak exercise) has been used by Balke (3:84, 4:765) in classifying various groups. His classification has been supported in part by the work done by Alexander et al. (1:21). It was found that athletes have better performance times than non-athletes. It was also found that medical students could better their performance times considerably by a 15 week program of 5BX exercises (1:21). This program was participated in five days a week for eleven minutes per day.

After the subject's heart rate reached 175 beats per minute, it was taken every half minute. The treadmill was stopped as the subject's heart rate reached 180 beats per minute. Just prior to stopping the treadmill, a nose clip was placed on the subject and he was instructed to breathe through a mouth-piece. The expired air was collected in three serially arranged Douglas bags during a three minute recovery period. The first bag was collected for one minute immediately following stopping of the treadmill. The second bag was collected during the second minute and the last bag was collected during the third minute. The oxygen consumption per kilogram of body weight per minute was calculated from the volume and oxygen percentage values obtained from these bags.

The percent oxygen was measured with a Beckman oxygen analyzer[1] and the volume was measured by pumping the contents of the bags through a gasometer[2].

Heart rate was recorded at the end of each minute for five minutes during recovery from the exercise.

Method of Determining Oxygen Consumption

The expired air was collected in Douglas bags. From the bag a samll sample of air was passed through a Beckman oxygen analyzer. This reading was corrected for barometric pressure to standard pressure. The correction was as follows: (reading in percent O_2) x $\frac{760}{B.P.}$

The volume of expired air was determined by passing the contents of the bag through a gasometer at a constant rate of 70 liters per minute with a centrifugal pump[3]. The amount of air used for the sample in determining oxygen content was added to the reading obtained. The total volume was corrected for temperature and pressure, to standard pressure and temperature dry. This was done by using the factors given in tables supplied by Warren E. Collins Inc. (8:27). For the calculation of oxygen consumption, it was assumed that the inspired air volume was equal to the expired air volume, i.e. that the respiratory quotient was unity.

It must be realized that this value is not an absolute value for oxygen consumed. To obtain a more accurate

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1 Beckman Oxygen Analyzer, Model C2, Fullerton California.
2 American Meter Company, Model 802, Boston Massachusetts.
3 Warren E. Collins Inc., Boston, Massachusetts.

value, the partial pressure of carbon dioxide should also be determined. However, the method used in this study showed relatively small differences for comparative purposes.

Initial Treadmill Test

The treadmill used in this study was equipped with a heavy canvas belt which ran on a smooth wooden slipway which supported the weight of the subject.

One week after the preliminary trial the subjects were tested again. This was called the initial test, because it was used to establish an initial level of circulo-respiratory fitness of the subjects. The subjects were requested to take part in no activity other than walking to and from classes, previous to the treadmill test on the test day. The subjects arrived in the laboratory in their gym suits, and rested for three minutes in a chair while preparations for the test were carried out. No warm-up was allowed before the initial of final tests. With the exception of the warm-up, the tests followed the same procedures as were outlined for the preliminary trial.

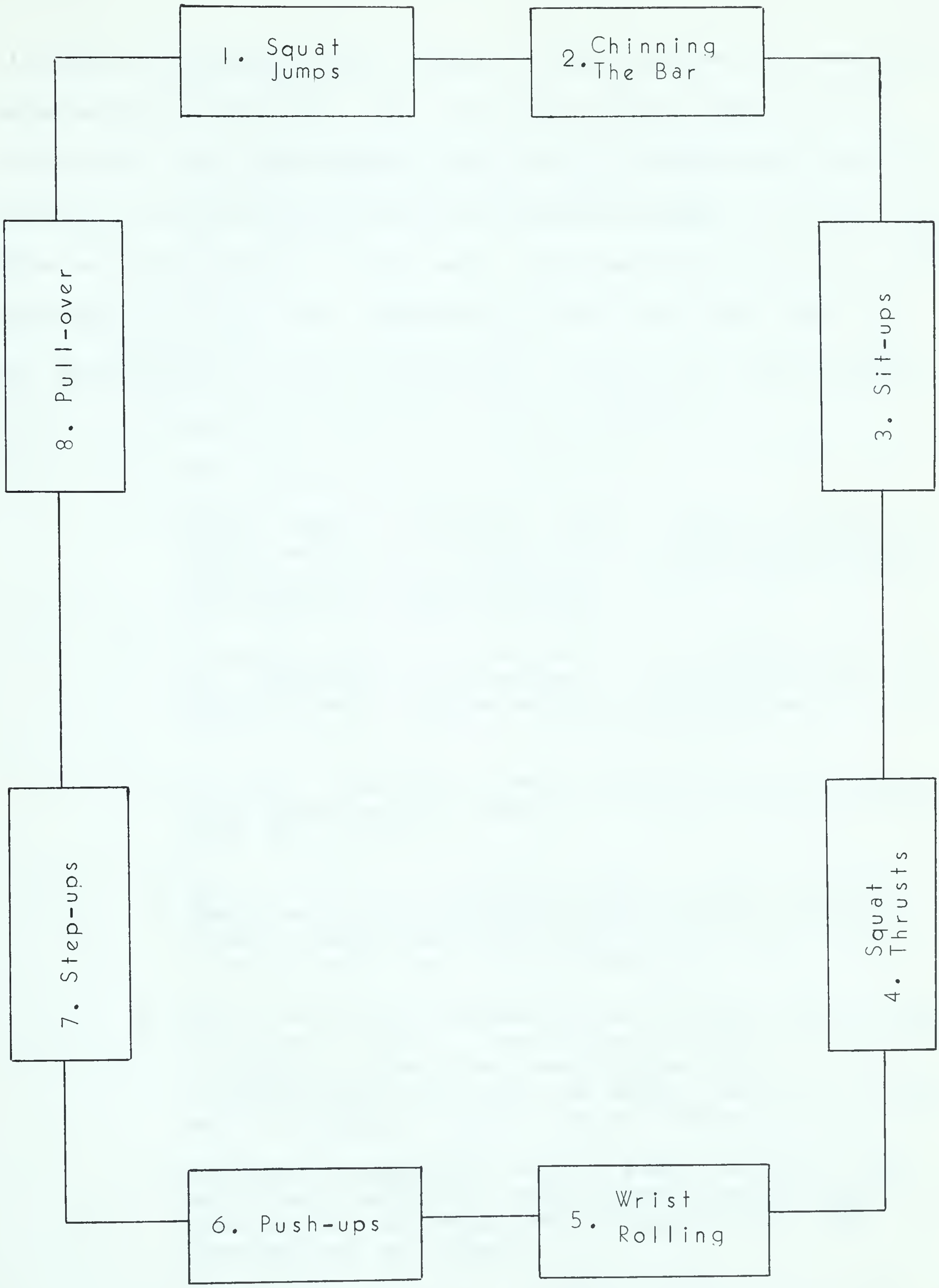
From the performance times of subjects in the initial test, three groups of subjects were established. The groups were chosen by the matching by pairs technique as discribed by Garrett (5:228). This system of selection was used until three groups of 15 were obtained. The treatment for a particular group was by random selection. Group A did circuit

training, Group B isometric exercises, and Group C was the control group.

Training Procedures

Circuit training group. The circuit training program consisted of the eight exercises used in the circuit described by Howell and Morford (6:12). It differed in the manner in which the training dose was determined for the subjects. In Howell and Morford's circuit the number of repetitions done by a subject at each station was determined by finding the maximum number of repetitions of the exercise each subject could do in one minute. Then the training dose was determined by halving to the nearest whole number the maximum done in one minute. For example, if a student did 16 chin-ups in one minute, his training dose would be eight chin-ups. The circuit consisted of three laps, each lap consisting of eight items, each performed at the training dose (6:13). When a student could complete the circuit within the stated time limit of ten minutes, his training dose at each station was increased either arbitrarily or by means of a retest. The student would then go through the circuit doing each exercise at the newly established training dose.

The training dose for each item of the circuit used in this study was determined before the group started training on the circuit. This was done by taking six students of average ohysical ability and placing them on each item of the circuit and allowing them to do as many repetitions of each



SCHEMATIC DIAGRAM OF CIRCUIT TRAINING PROGRAM

item as they could in one minute. A one minute rest was given between each exercise. The starting training dose at each station for the group doing the circuit in the study was calulated by taking one-third of the maximum number of repetitions done at each station. The number of repetitions which was added when the circuit was completed within the time limit was set beforehand and was designed to increase the load progressively in increasing difficulty (see appendix).

The items used were as follows:

1. Squat jumps - equipment none. Hands on hips, one foot ahead of the other in full squat position; jump into the air and land in squat position again with opposite foot forward.

2. Chinning the Bar - equipment, a high bar, erected or suspended in any manner. Stand below the bar, grasp it with narrow reverse hold and pull up until chin touches bar; return to hang position.

3. Sit-uos - equipment none. Back lying on floor or mat, hands behind head, roll up to sitting position and return.

4. Squat Thrusts - equipment none. From standing position to squat position by placing hands on floor between feet, extend feet to rear and return to squat position; stand up.

5. Wrist Rolling - equipment, an 18 inch window cord attached at center and suitable 10-15 pound weight attached to the other end of the cord. In a standing position wind the weight up to the handle by rotating the stick in both hands, then unwind.

6. Push-ups - equipment none. Body in face-lying position, hands on floor, palms down by shoulders; extend arms and then lower, keeping the body straight at all times.

7. Step-ups - equipment, chairs 16-24 inches high, or a bench or bleacher seat. Facing the chair, step up and down on the chair without jumping and by

placing both feet on the chair before stepping off again.

8. Pull-over-back-lying, arms extended beyond shoulders, grip bar; keeping arms straight, pull bar to vertical position above chest, lower to thighs then return to starting position (4:13). A 25 lb. bar was used.

The circuit consisted of three laps, each lap consisting of the eight items above, each performed at the training dose set beforehand. When a subject could complete the circuit in ten minutes, he progressed to a larger load which consisted of more repetitions of each exercise.

The circuit training group met three times per week for ten minutes for five weeks. Twice per week they met after 25 minutes of badminton participation in the regular physical education class. These sessions were supervised by the writer.

Isometric exercise group. The isometric exercise group followed the program of exercises outlined by Hoffman (7:20). The exercises were done on a multi-purpose apparatus built at the University of Alberta and illustrated on figure I. Figures II and III illustrate the exercises done. The exercises as described by Hoffman were as follows:

1. Press Lockout. Set the bar at a height about three inches below the lock out position, arms fully extended overhead. Grasping the bar with hands about shoulder width apart, look straight ahead, tighten leg, hip and back muscles and push on bar as hard as possible for 10 seconds.

2. Press start. Set the pins about chin height, use same grip as in exercise no. I. Again tighten legs, hips and back muscles, look

straight ahead and push on bar as hard as possible for 10 seconds.

3. Rise on toes. Set the bar at a height where it will rest just touching or a little above your neck and shoulders, when you are standing in front of it in an erect position. Keep the knees and hips locked tight, the back straight, and the head slightly turned back. Hold hands on bar at a comfortable position. Rise on the toes and push on the bar as hard as possible for 10 seconds.

4. Pull. Set the bar at a height where it will be six or seven inches below the waist. Use same grip as in No. 1. and 2., rise on toes slightly, look up slightly, bend the arms and pull as hard as you can for 10 seconds.

5. Parallel Squat. Set the bar at a height where it will rest on the back of the neck and shoulders when you are in a squat position with the thighs parallel to the floor. Place the hands on the bar in a comfortable position and rise, pushing with the legs as hard as possible for 10 seconds.

6. Shoulder Shrug. Set the bar at a height where it will be in your hands when your arms are fully extended downward. Grip the bar with hands about shoulder width apart. Shrug the shoulders upward as hard as possible for 10 seconds. Keep the arms and legs fully extended at all times.

7. Dead Weight Lift. Set the bar at a height where it will be about two inches below the knees, when you are holding it with hands about shoulder width apart. Keep the head up, the hips down and the back flat. Push hard on the legs and pull up as hard as you can for 10 seconds.

8. Quarter Squat. Set the bar at a height about four inches below the height it would be if you were standing erect. Grip the bar with the hands in a comfortable position, and push up with the thighs as hard as possible for 10 seconds. Keep the head up, the back flat, and the heels on the ground.

Each exercise was done with a maximum contraction held for eight seconds with an eight second rest between each contraction. A 30 second rest was allowed between exercises.

MULTI-PURPOSE ISOMETRIC-ISOTONIC EXERCISE APPARATUS

Scale ½" = 1'

Prepared by:
Dr. M.L. Howell,
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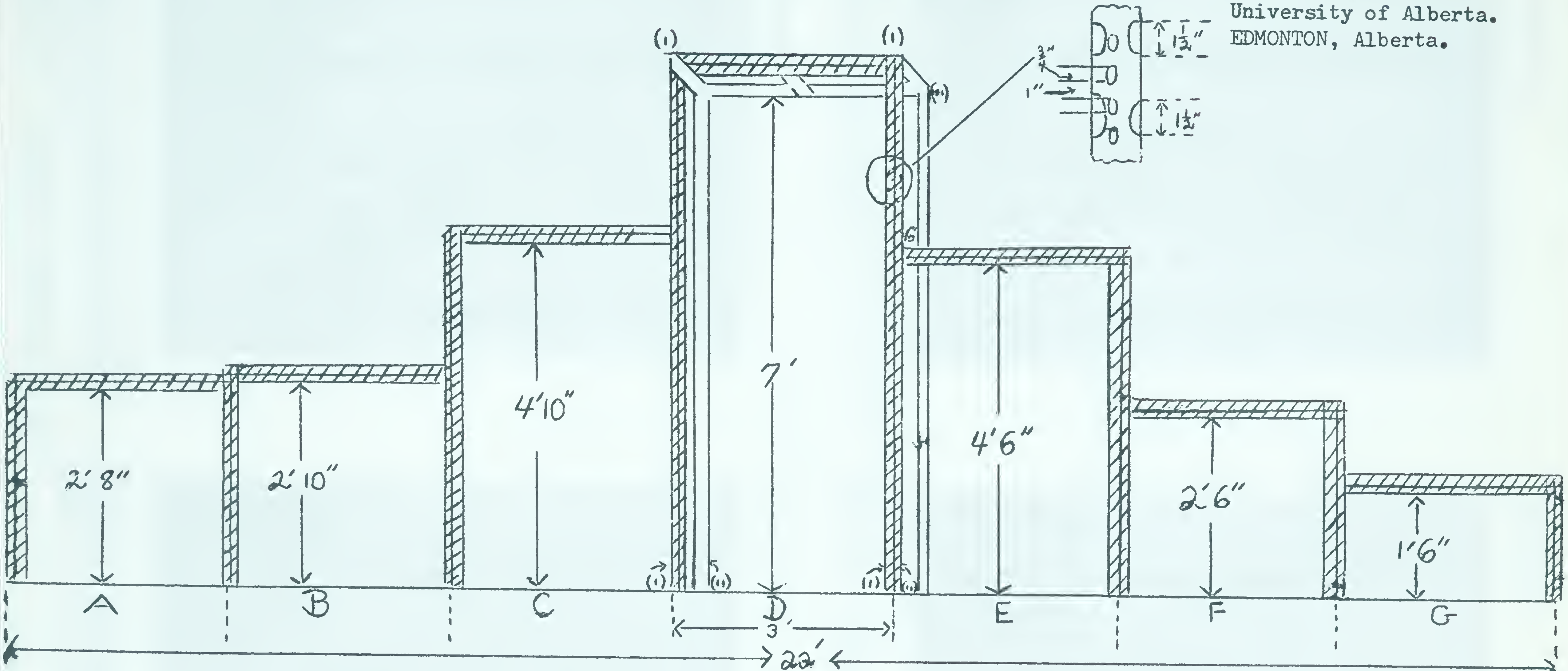
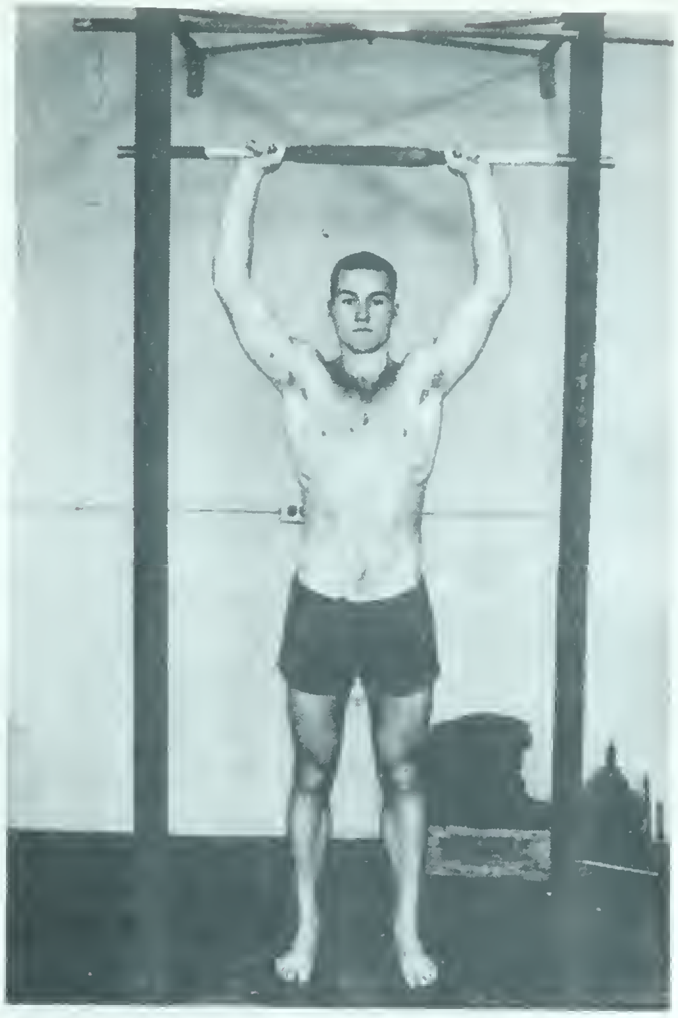


1. Use 2" pipe
2. All measurements from center to center.
3. Apparatus should be fixed at a minimum of 2' from wall.
4. Foam rubber should be taped to bar at stations involving back of neck.
5. At station "D" there are two rectangular frames (7' x 3') set 6" apart, joined and braced at the top. In Frame (1) 1½" holes, 2" apart are drilled from top to bottom to accommodate a ¾ " bar between sides of frame (1). These are not done in Frame (11). In (1) &(11) ¾ " holes are drilled 1" apart on front of bars so ½" bolts may be placed between the frames to enable isotonic work.

FIGURE I - MULTI-PURPOSE ISOMETRIC-ISOTONIC EXERCISE APPARATUS

EXERCISE #1

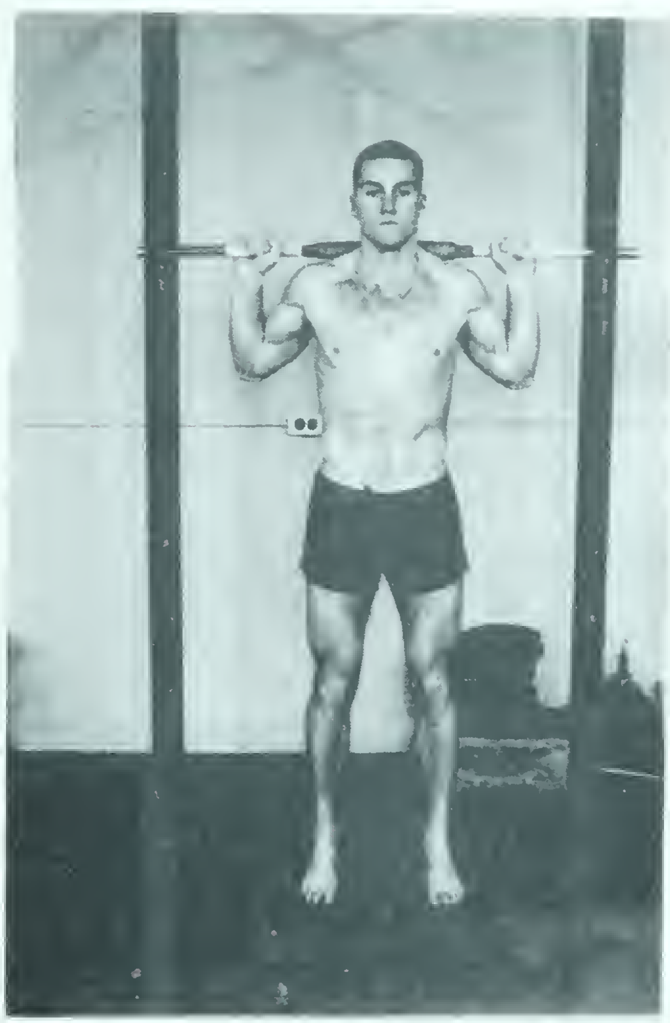


HANDS PLACED ON BAR SHOULDER WISTH APART AND ARMS SLIGHTLY BENT. BODY STRAIGHT AND FEET FLAT. PUSH UPWARD.

EXERCISE # 2

BAR HALD AT CHIN LEVEL. HANDS SHOULDER WIDTH APART. FEET FLAT. PUSH UPWARD.

EXERCISE # 3



BAR HELD BEHIND HEAD ON THE SHOULDERS. HANDS PLACED COMFORTABLY ON THE BAR. FEET FLAT AT BEGINNING. PUSH UPWARD WITH WHOLE BODY.

EXERCISE # 4

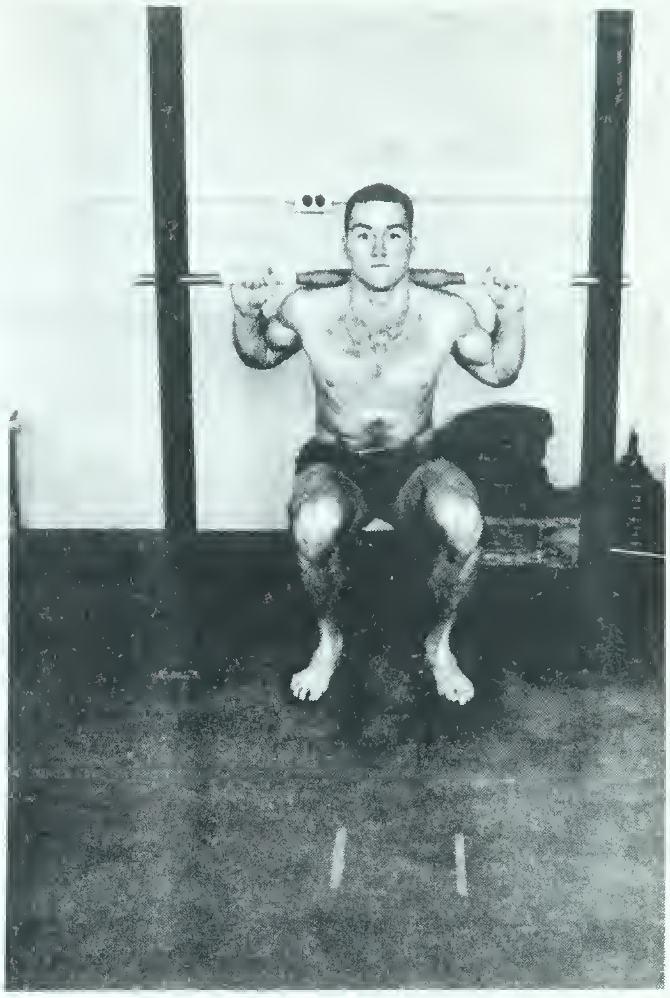
BAR HELD AT POINT ONE LEVEL ABOVE FULL ARM LENGTH. STANDING ON TIP-TOES WITH ARMS BENT. PULL UPWARD WITH ARMS REMAINING BENT.

FIGURE II - ISOMETRIC EXERCISES I - IV

EXERCISE # 5

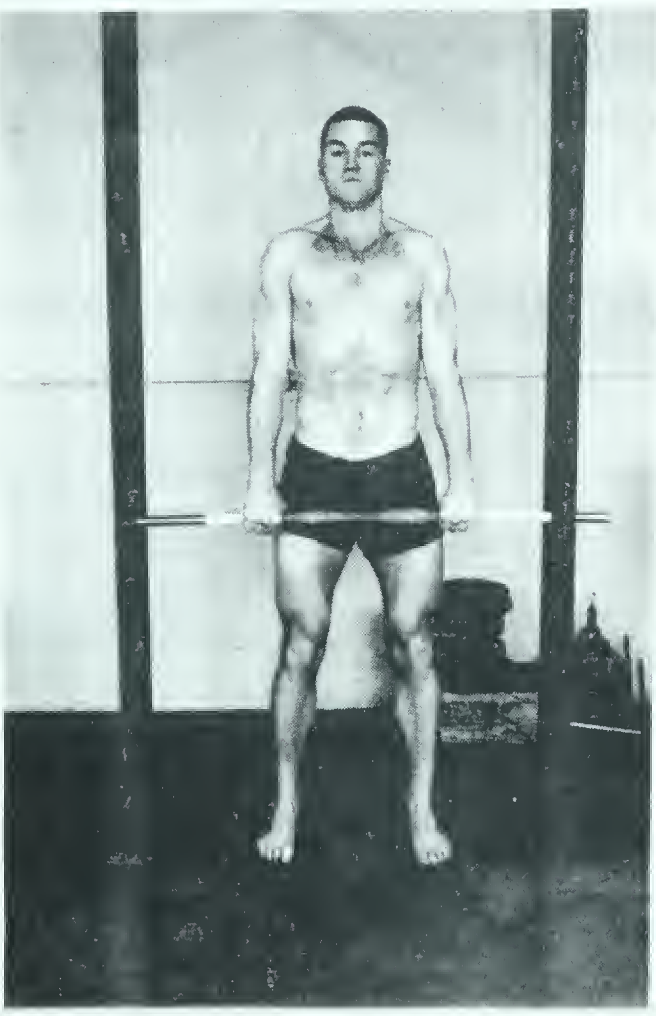
BAR PLACED AT KNEE LEVEL. FEET FLAT. HEAD UP. BACK STRAIGHT. PULL UPWARD

EXERCISE # 6



BAR PLACED BEHIND HEAD ON SHOULDERS. FEET FLAT. UPPER LEG PARALLEL TO FLOOR. ANGLE AT KNEE APPROX. 90°. PUSH UPWARD.

EXERCISE # 7



BAR PLACED AT FULL ARMS LENGTH. FEET FLAT. PULL UPWARD WITH THE SHOULDERS.

EXERCISE # 8

BAR PLACED BEHIND HEAD ON SHOULDERS. FEET FLAT. KNEES BENT. PUSH UPWARD TRYING TO STRAIGHTEN THE LEGS.

FIGURE III - ISOMETRIC EXERCISES V - VIII

This allowed time for the subjects to change position and get ready for the next exercise. The importance of maintaining a maximum contraction for the three repetitions of each exercise was stressed. Each training session took approximately ten minutes. The exercises were done three times per week for five weeks. Two training periods per week were supervised by the writer and were held after 25 minutes of badminton participation in the regular physical education class.

Control group. The control group was instructed not to take part in any activity during the experimental period which was of a regular or strenuous nature. They did, however, convene twice weekly for their physical education classes together with members of the circuit training group and isometric exercise group. The classes met twice per week for 35 minutes each period and were instructed in the fundamentals of badminton. Maintenance of equated groups was further preserved in view of the fact that the author instructed the same activity (badminton) to all classes where subjects were registered.

Final Test

The final treadmill test was conducted in the same manner as the initial treadmill test. A recall form was used to determine the kind and extent of all activities engaged in over and above those prescribed by the study.

Thirty-three subjects were used in the final analysis of the data. The number was reduced to this because of illness, excessive absences or participation in activities outside of the study.

Test-retest Reliability

Test-retest reliability between the preliminary treadmill trial and the initial treadmill test was studied with the 33 subjects used in the statistical analysis of the study.

Statistical Treatment and Design

Three equated groups of fifteen subjects were used in the study. The groups were equated on the basis of treadmill performance times (for individual scores see Appendix C).

The results of the final treadmill performance test were treated by analysis of variance to test the hypothesis. In the event that the hypothesis were rejected the t-test was applied to ascertain the statistical significance of observed differences between individual groups. Also, the t-test was used to study the within group differences between mean treadmill performance times in the initial and final tests.

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CHAPTER IV

RESULTS AND DISCUSSION

The data for this study were secured from 33 male subjects attending Physical Education service courses at the University of Alberta during the Fall Term of 1962.

The mean age and weight of the subjects is shown in Table I.

TABLE I

Mean Age and Weight of

Subjects Participating in the Study

Group	Mean Age (yrs.)	S.D.	Mean Weight (kgs.)	S.D.
Circuit training	18.7	2.1	67.6	8.0
Isometric Exercises	18.5	1.0	73.2	9.8
Control	18.8	1.0	72.0	8.3
N = 33				

Results

Reliability of Test. The Pearson Correlation Coefficient (1:258) was used to determine the reliability of the treadmill test. The data for this coefficient of correlation were obtained from the preliminary trial and the initial test of the study, one week later. The mean treadmill performance time of the preliminary trial was 13.7 $\pm$ 2.18 minutes and the mean treadmill performance time of the initial test was 14.3 $\pm$ 2.29 minutes. The coefficient of correlation

between the two tests was .842.

<u>Between Group Comparison</u>. Analysis of variance (2:270) was used to test the hypothesis that all three groups came from the same population in terms of the factor being tested i.e. that obtained differences in treadmill performance time could be attributed to chance. In the event that the hypothesis was rejected the t-test was applied to ascertain the statistical significance of observed differences between individual groups.

Table II shows the variance analysis of the three groups with the degrees of freedom and mean squares.

TABLE II

Variance Analysis of Treadmill

Performance Times of the Three Conditions

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Squares	F - Ratio*
Between Groups	66.39	2	33.195	4.22
Within Groups	235.91	30	7.864	
Total	302.30	32		

* F at .05 level of confidence = 3.32
* F at .01 level of confidence = 5.39

The analysis of the over-all difference between final treadmill performance times of the three groups produced an F-ratio of 4.22 which was significant at the .05 level

of confidence (Table II). Thus the null hypothesis was rejected and the alternate hypothesis accepted. Use of the t-test for between groups differences yielded a statistically significant difference between the means of the circuit training group and the isometric exercise group at the .05 level of confidence (t = 2.42 in Table III).

TABLE III

Comparison of Results Between Groups On Final Mean Treadmill Performance Times

Group	Mean (Min.)[2]	Mean Difference	S.E. Difference	d.f.	t*
Circuit	17.27	1.72	.711	10	2.42
Isometric	15.55				
Isometric	15.55	.45	.575	10	.78
Control	16.00				
Circuit	17.27	1.27	.775	10	1.64
Control	16.00				

*t at .05 level of confidence = 2.23

The difference between means of the final test of the circuit training group and the control group was not statistically significant (t = 1.64). Also the difference between means of the isometric exercise group and the control group in the final test was not statistically significant (t=.78).

<u>Within Groups Comparison</u>. The method of equivalent groups as described by Garrett (2:228) was used to study the differences between mean treadmill performance times of the groups in the initial and final tests. Table IV shows the means and standard error of the differences on the initial and final tests for all groups.

TABLE IV

Comparison of Mean Gains of Three Groups Between Initial and Final Treadmill Performance Tests.

Treadmill Test (in Min.)	M_1	M_2	$M_2 - M_1$	S.E. Diff.	d.f.	t*
Circuit Training Group	14.32	17.27	2.95	.550	10	5.36
Isometric Exercise Group	14.27	15.55	1.28	.338	10	3.30
Control Group	14.27	16.00	1.73	.377	10	4.59

* Significant to the .01 level of confidence. (t = 3.17)

The mean increase in treadmill performance time of all three groups was statistically significant beyond the 1 percent level of confidence. The circuit training group mean treadmill performance time initially was 14.32 minutes with a standard deviation of 2.45 minutes. The final mean performance time was 17.27 minutes with a standard deviation of 3.11 minutes. The difference between means of 2.95 minutes, was statistically significant at the 1 percent level of

confidence (t = 5.36). The mean treadmill performance time of the isometric exercise group initially was 14.27 minutes with a standard deviation of 2.36 minutes. The final mean performance time was 15.55 minutes with a standard deviation of 2.72 minutes. The difference between the means of the two tests was 1.28 minutes and was statistically significant at the 1 percent level of confidence (t = 3.30). The initial mean treadmill performance time of the control group was 14.27 minutes with a standard deviation of 2.40 minutes. The final mean performance time was 16.00 minutes with a standard deviation of 2.55 minutes. The difference between means of the two tests was 1.73 minutes and was statistically significant at the 1 percent level of confidence (t = 4.59).

Pre - Exercise Heart Rate

The mean pre-exercise standing heart rate for all three groups for the three different testing days was calculated. Figure IV presents this data graphically. In each group, except the control group, the mean pre-exercise heart rate on the first trial was higher than on the initial treadmill test. This difference was not apparently significant. With the control group the mean pre-exercise heart rate on both the preliminary trial and on the initial test was the same. The mean pre-exercise heart rate on the final treadmill test was less than on the initial treadmill test for the circuit training group and the control group but was

The same for the isometric exercise group. However, the differences were too small to be of significance. In the circuit training group the mean pre-exercise heart rate was only one beat per minute less. For the control group the difference was three beats per minute (see figures IV, V, VI).

Considering the large individual variations from test to test, it could be said that there was no difference in mean pre-exercise heart rate on any of the test days.

Recovery Heart Rate

The mean recovery heart rate for each group on each of the three test days was calculated for each minute during five minutes of recovery. The results are shown on figures IV, V, VI.

The mean heart rate at the end of the first minute of recovery for all groups during each test day varied only from 131 beats per minute to 138 beats per minute. There was no observable pattern in this difference either between groups or within groups.

Similarly no difference in recovery heart rate was observed between groups at the end of succeeding minutes. Also there was no apparent differences in recovery heart rate as a result of trials. The final mean recovery heart rate was not apparently different from the initial mean recovery heart rate. One exception to this pattern should be noted. It was observed that the mean recovery pulse rate of the control group was higher than that of the other groups.

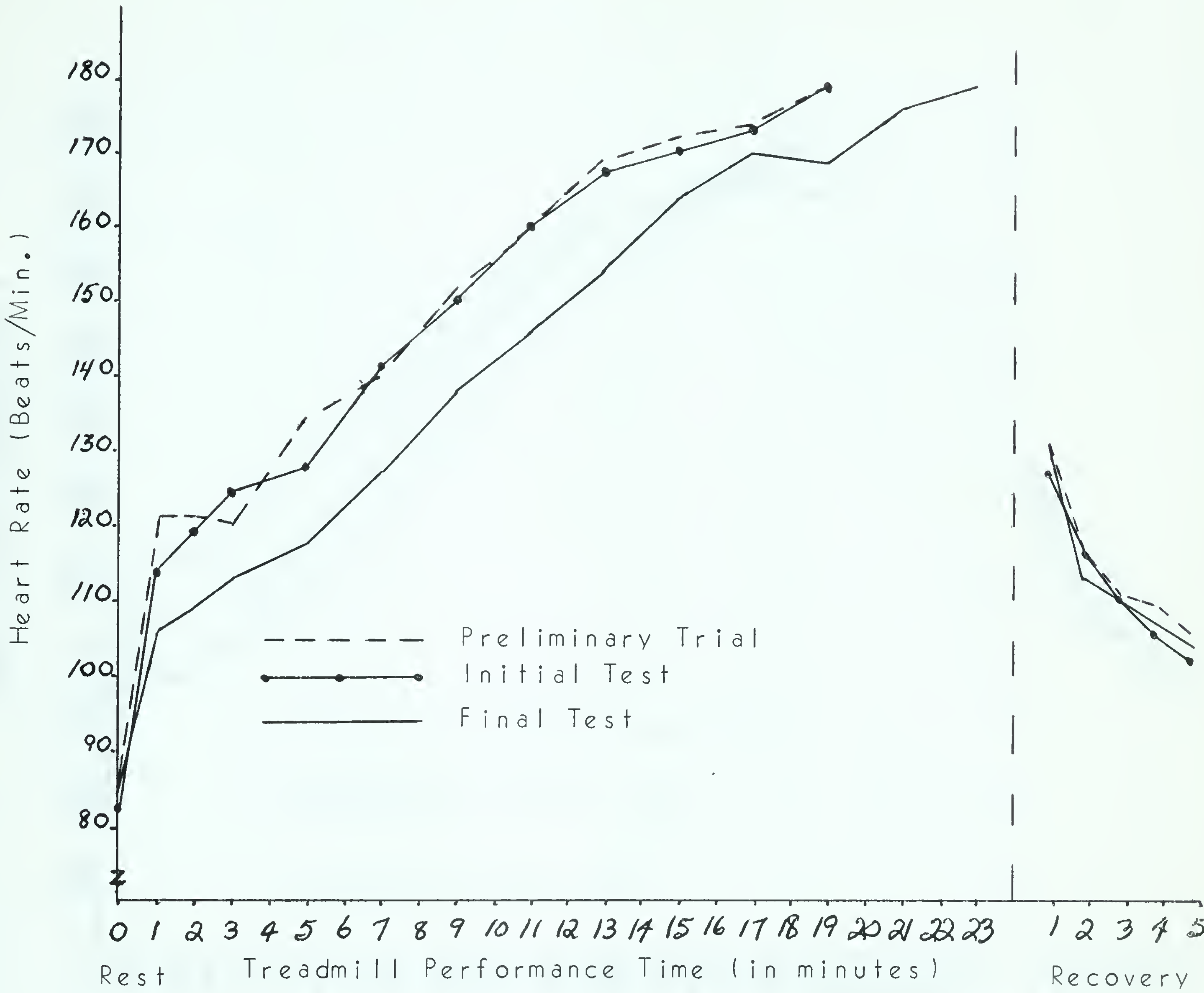

FIGURE IV

MEAN HEART RATE DURING EXERCISE AND RECOVERY

(CIRCUIT TRAINING GROUP)

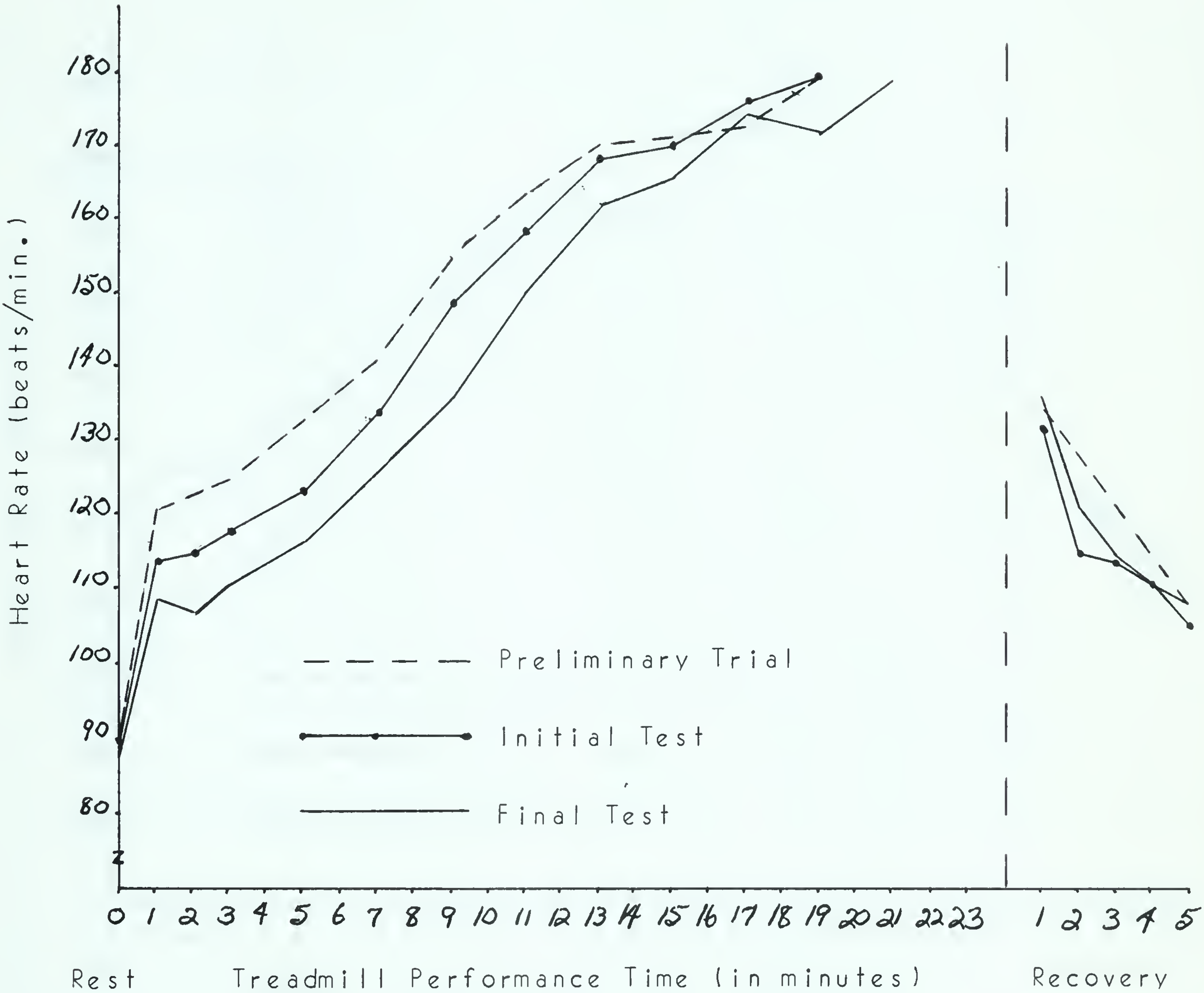

FIGURE V

MEAN HEART RATE DURING EXERCISE AND RECOVERY

(ISOMETRIC EXERCISE GROUP)

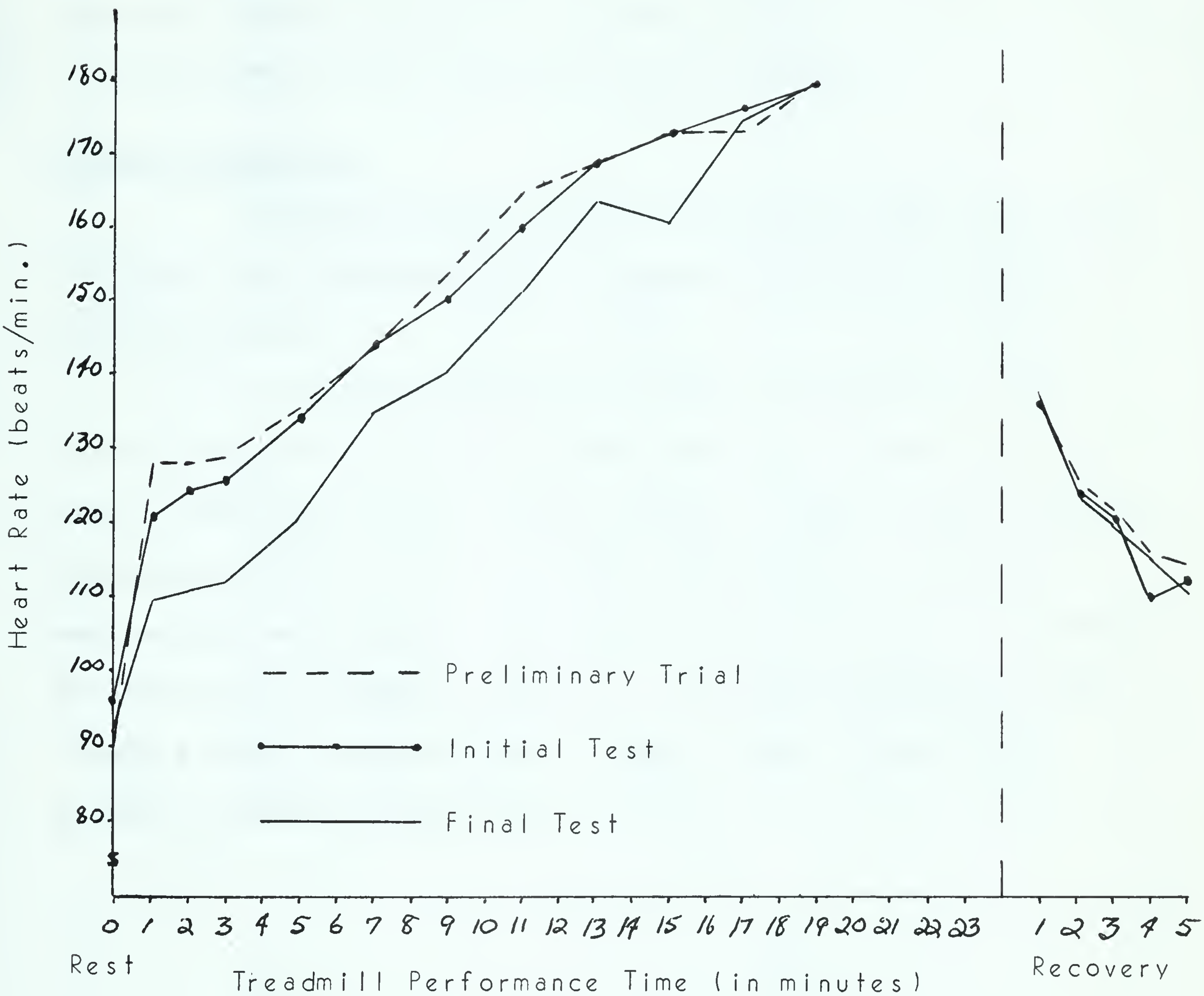

FIGURE VI

MEAN HEART RATE DURING EXERCISE AND RECOVERY

(CONTROL GROUP)

However, it should also be noted that the mean resting pulse rate was higher in the control group than that of the circuit training group or the isometric exercise group.

Oxygen Consumption

Oxygen consumption before the start of the treadmill test was determined for all subjects on the initial and final test days.

Figure VII shows the oxygen consumption on the initial and final test days before exercise and during recovery from exercise for three minutes. These values are expressed as milli-liters of oxygen consumed per kilogram of body weight per minute. The exact values with their standard deviations are shown on Table V. The oxygen consumption per minute without consideration of body weight according to groups is shown in Table VI.

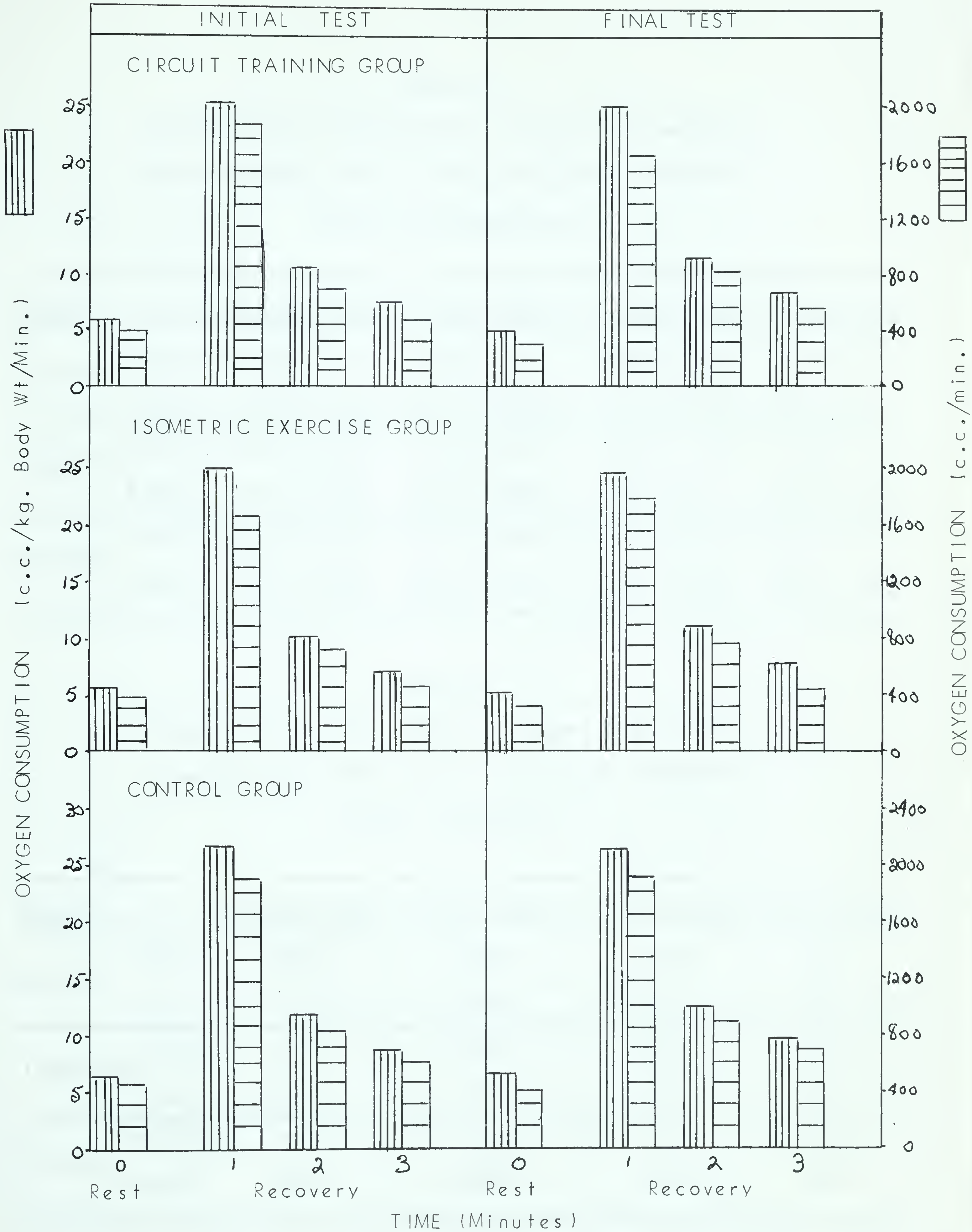

FIGURE VII PRE-EXERCISE AND RECOVERY OXYGEN CONSUMPTION

TABLE V

Pre-Exercise and Recovery Oxygen Consumption Averages for the Initial and Final Treadmill Tests (cc./kg./min.)

Group		Pre-exercise	1 min. Rec.	2 min. Rec.	3 min.Rec.
Circuit	Initial	5.9 ± 1.1	25.2 ± 2.7	10.9 ± 1.7	7.7 ± 2.3
	Final	5.0 ± 1.1	27.5 ± 4.4	11.8 ± 3.6	8.6 ± 1.1
Isometric	Initial	5.4 ± 0.9	24.9 ± 4.6	10.6 ± 1.8	7.3 ± 1.2
	Final	5.1 ± 0.4	24.8 ± 2.9	10.8 ± 2.1	7.8 ± 1.6
Control	Initial	5.9 ± 0.8	26.8 ± 4.6	11.4 ± 2.5	8.4 ± 1.5
	Final	5.7 ± 2.2	26.8 ± 4.5	12.6 ± 2.3	9.5 ± 1.8

TABLE VI

Pre-exercise and Recovery Oxygen Consumption Averages for the Initial and Final Treadmill Tests (cc./min.)

Group		Pre-exercise	1 min. Rec.	2 min. Rec.	3 min.Rec.
Circuit	Initial	396	1,696	736	511
	Final	302	1,850	854	581
Isometric	Initial	391	1,661	768	530
	Final	375	1,808	783	512
Control	Initial	419	1,926	815	600
	Final	394	1,913	911	691

The pre-exercise oxygen consumption in milliliters per kilogram of body weight per minute tended to be less after the experimental period than before in all three groups (Table V). However, this difference was only in the order of one ml./kg./min. The largest difference occurred in the circuit training group and this difference was not statistically significant ($t = 2.17$). Oxygen consumption during the first minute of recovery increased after training in the circuit training group but tended to remain the same in the other groups. During the second and third minutes of recovery the oxygen consumption per kilogram of body weight tended to increase after the training period in all three groups. Again this increase was only about one ml./kg./min. in the circuit training group and control group. The difference was less for the isometric exercise group. These differences were apparently not significant since the number of subjects tested was small and individual variations were large.

Ventilation Equivalent

The amount of oxygen obtained by the individual per liter of air inspired was calculated for all subjects for the initial and final tests. The means for each group are shown on Table VII.

TABLE VII

Pre-exercise and Recovery Ventilation

Equivalent for Initial and Final Tests

(cc./lit./min.)

Group		Pre-exercise	1 min.Rec.	2 min.Rec.	3 min.Rec.
Circuit	Initial	38.4	48.9	37.4	36.7
	Final	37.9	47.2	38.3	37.3
Isometric	Initial	36.6	45.4	36.8	34.8
	Final	37.0	45.8	37.0	34.8
Control	Initial	37.2	46.4	33.1	34.1
	Final	38.7	47.2	36.7	35.1

Discussion

In the problem the null hypothesis asserted that the means of the three different conditions, circuit training, isometric exercises and control activity, differ only through fluctuations of sampling. This was tested by the analysis of variance method and the resulting F-ratio ($F = 4.22$) showed that one mean was reliably different from at least one other mean. Thus the null hypothesis was rejected and the alternate hypothesis accepted. The "t-test" analysis showed that there was a statistically significant difference between the final means of the circuit training group and the isometric exercise group in favour of the circuit training group. There was

no statistically significant difference between means of either the control group or between means of the control group and the isometric exercise group.

On analysis of the within group changes in treadmill performance times, it was found that all three groups improved significantly at the .01 level of confidence. This fact, accompanied with the fact that there was no statistically significant difference between the control group and either the circuit training group or the isometric exercise group, indicated that ten minutes of circuit training or ten minutes of isometric exercises, three times weekly, are no more effective in improving treadmill performance time than is badminton.

The activity recall sheets were analysed and in particular those of the control group, to discover if any outside activity had influenced the final mean treadmill performance times. Of the 33 subjects remaining in the study, no evidence of outside activity which might have affected the study was found. Subjects took part in intramurals, once per week, but did not work out regularly. It was felt that this was a normal amount of activity to engage in, and subjects were not rejected on account of it.

The reliability of the treadmill test was found to be high ($r = .84$) for the test re-test of 33 subjects used in the study. In another study (3: 5) the test-retest reliability was found to yield a correlation coefficient of .96.

On this basis it was felt that learning had not affected the final treadmill performance times.

It is important to point out that the results obtained in this study are those for the particular circuit training program used and the particular isometric exercise program used. It is conceivable that different results may have been obtained if a circuit with different exercises had been used or if a circuit with a time limit of 15 minutes had been employed. Similarly, isometric exercises with more repetitions of each exercise held for shorter or longer periods of time may have produced different results. In this study, an attempt was made to take into consideration the variable of training time as discussed by Slater-Hammel (4:236). As stated in his comments, "Many ambiguities may be avoided by following this one rule: vary the treatment comparisons in a single, clearly specified way". On this reasoning, the isometric exercises were repeated, rather than held for a single maximal contraction, so that the training time and frequency was equal to the training time and frequency of the circuit training group. According to Hettinger and Müller (5:6) development of strength is maximal with one 2/3 maximal contraction of a particular muscle group held for six seconds daily. Liberson and Asa (6) obtained contradictory evidence. They used the abductor finger of one hand as experimental and the abductor finger of the other hand as control. Isometric contractions repeated 20 times gave better

results than a single contraction. Just what training dose is required for devlopment of endurance, if this is possible, is not known. It is the opinion of two noted researchers, Karpovich and Steinhaus (7:21), that isometrics will not develop endurance. Delorme (8) says, "Power building exercises and endurance building exercises are two entirely different types, each one producing its own results, and each being wholly incapable of producing the results obtained by the other". The results of this study do not condradict these statements, since circulo-respiratory capacity as measured by the treadmill performance test was not changed by either experimental activity.

On analyzing the possibilities of isometric exercises to produce circulo-respiratory endurance effects, it can be seen that isometric exercises have little in their favor. Capillarization, necessary for the development of circulo-respiratory endurance, is not affected by isometric exercises (9). However, it has been shown by Howell et al. (10:536) and Swegan (11), that isometric exercise improve muscular endurance. The distinction between circulo-respiratory endurance and muscular endurance is not clear. In its general context, circulo-respiratory endurance is the ability of the whole body to sustain prolonged activity in which circulo-respiratory mechanisms are the limiting factors. Muscular endurance is "The capacity of the individual for continuous performance of relatively heavy localized activity. It makes small demands

on the functions of respiration and circulation before local exhaustion sets in. It depends to a large extent on strength, but also on the efficiency of the blood supply in the muscle tissue" (12:17).

In tests of circulo-respiratory endurance, the onset of fatique is offset by an improvement of heart function. The improvement in heart function is brought about in two ways. One is by a slowing of heart rate and the second is by attaining an optimum heart size (13:69). Hypertrophy of the heart would occur if, during isometric contractions of large muscle groups, the heart was forcing blood through the systemic system under an increased blood pressure. However, it is hypothesised that during isometric contractions the heart is beating against a reduced blood pressure because of the Valsalva manoeuver. The Valsalva effect is produced by a deep inspiration prior to an isometric contraction and the holding of the breath throughout the contraction. Thus during a contraction, the heart rate is less and the arterial blood pressure falls. Accompanying this is an increase in venous blood pressure. The fall in arterial blood pressure is due to the reduced venous return caused by the increased intrathoracic pressure.

In a series of isometric contractions with rest periods between each contraction it has been shown that during isometric contractions of large muscle groups the heart rate is less than during the rest periods, (14).

The measurements of pre-exercise oxygen consumption, oxygen consumption during three minutes of recovery, pre-exercise heart rate and heart rate during five minutes of recovery did not apparently change as a result of the experimental conditions. The training effect as measured by the treadmill performance times was not accompanied by changes in heart rate or oxygen consumption either before exercise or during recovery. It has been shown by Nagle and Irwin (15:607) that forms of weight training do not affect these measures. C.L. Taylor (16:614) says, "...except for a small but consistent reduction in heart rate, changes in resting functions are either nonexistant or slight". He also says, "Pulse recovery has been shown to have limited validity after submaximal exercise and after maximal exercise" (16:614).

There are a number of problems associated with physiological measurements as used in this study both during and after exercise. As Taylor and Brozek (17:216) mention, the majority of fitness tests appear to be simple. "However, the functions measured are subject to a great variety of influences and it is necessary to apply the most rigid control of environmental, physiological and psychological conditions under which measurement is carried out." Such things as pre-test exercise, time relation to meals, psychological atmosphere and temperature and humidity must be considered. It has been shown that temperature and humidity influence heart rate (16:217).

In this study an attempt was made to control ore-test exercise by stressing the point that no activity be done other than walking to and from class on the test day. However, even this would vary from subject to subject and from day to day. Similarly, the other variables mentioned above, were not adequately controlled in this study.

The method of determining oxygen consumption was subject to error since the percentage of carbon dioxide in the expired air was not determined for the calculation. It was assumed oxygen consumption equalled the carbon dioxide production and that the resoiratory quotient was one (R.Q. = 1). Since nitrogen is metabolized to a very slight degree, it was oossible to equate volume of expired air with volume of inspired air on the basis of our assumotion. The values for oxygen consumption obtained are therefore, not accurate absolute values; they are only comparative values, and should be regarded as such when interpreting the results.

Also the ventilation equivalent, a measure of the efficiency of the respiratory system, did not change during the five weeks of the study. The variation in extraction of oxygen in milli-liters per liter of inspired air per minute was greatest during the second minute of recovery on the initial and final test days of the control group. The variation in this case was only 3.6 ml./lit/min. In most cases, the differnece in ventilation equivalent in any group on initiai and final test days was only about 1 ml./lit./min.

It must be pointed out that the control group as used in this study did not control the study. Since the mean treadmill performance times of the "control group" changed significantly from initial to final test days, changes produced by the circuit training and the isometric exercises were masked. Also, since there was no difference between the circuit training group and the control group or the isometric exercise group and the control group, it must be said that the differences within groups were caused by the badminton participation. But, it must be assumed that the badminton activity had equal effect on both experimental groups. Since there was a statistically significant difference between the circuit training group and the isometric exercise group, it can be said that circuit training improves endurance as measured by the Balke treadmill test to a greater degree than will isometric exercises.

In studying the problem, one important area of investigation has not been comsidered. This is the effect of changes in body composition on heart rate. The effect of training on heart rate has been treated as an independent variable. The work of Buskirk _et al_. (18:86) suggests that changes in body composition due to training may affect the response of heart rate to exercise. They say, "...at equal body weight, and equal work done in walking, the heart rate is significantly and directly related to the percentage of the body weight represented by fat". However, they add, "The conclusion that the percent body fate is an important constitution-

al variable in determining the increase of pulse rate in work and recovery can not be made with certainty", (18:88).

In view of these findings it is recommended that future studies using work capacity test determined by a certain heart rate, consider changes in body composition where training is involved.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

It was the purpose of this study to investigate the effects of five weeks of an isometric exercise training program and five weeks of a circuit training program on treadmill performance as measured by the Balke treadmill performance test. Subsidiary problems were to investigate the effects of five weeks of an isometric exercise training program and five weeks of a circuit training program on: a) pre-exercise heart rate, b) pre-exercise oxygen consumption, c) heart rate during five minutes of recovery from exercise, and d) oxygen consumption during three minutes of recovery from exercise.

Fourty-five first year male subjects at the University of Alberta participated in the study. Each subject was tested twice on the Balke treadmill test during the first two weeks of the study. The first test was a preliminary trial to acquaint the 45 subjects with walking on the treadmill. The second test was given one week later to establish a base level of performance and also for test-retest reliability measurements. After this test three groups were selected from the fourty-five by equating the subjects on the basis of treadmill performance time. Group I was chosen to do circuit training, Group II was chosen to do isometric exercises, and Group III was chosen to be the

control group.

All the subjects continued to participate in the required physical education class twice per week for five weeks following the second treadmill test. The activity participated in was learning the fundamentals of badminton. Those in the circuit training group participated in the physical education class for 25 minutes and in circuit training the last ten minutes of each 35 minute class period. In addition to this, each week they went through the ten minute circuit once outside of the class period. Similarly, the isometric exercise group participated in badminton for 25 minutes of each class period and for ten minutes in isometric exercises. They also came to do isometric exercises for ten minutes once a week for the five week period. The control group participated in badminton the whole 35 minutes of each class period, twice per week for five weeks. A summary of the activity during the five weeks of the study is as follows:

Group	Class Activity	Training Period
Circuit training	Badminton, twice per week for 25 min. for five weeks.	Circuit training, thrice per wk. for ten min. for five weeks.
Isometric exercise	"	Isometric exercise, thrice per week for ten min. for five wks.
Control	"	Badminton, twice per wk. for ten min. for five weeks.

The exercises that the circuit training group did were those outlined by Howell and Morford (1:12). It consisted of eight exercises and the time limit was ten minutes. The isometric exercises used in the study were those described by Hoffman (2:21). Each of the eight exercises was held maximally for eight seconds for three repetitions with an eight second rest between contractions. A 30 second rest was allowed between exercises. The control group participated in learning the fundamentals of badminton in the regular physical education program for five weeks.

After five weeks all the participants were given a final treadmill performance test.

For all three tests, heart rate and oxygen consumption measurements were taken both immediately before treadmill walking and during five minutes of recovery immediately after treadmill walking. For oxygen consumption determinations, expired air was collected for each minute during the first three minutes of recovery. Heart rate was determined each minute for five minutes of recovery.

The data of the final treadmill performance times were treated by analysis of variance. The resulting F-ratio was 4.22, indicating that there was a difference between at least one mean and one other mean. The t-test analysis showed that there was a statistically significant difference between the final mean treadmill performance time of the circuit training group and the isometric exercise

group. There was no statistically significant difference between the means of the final treadmill performance times of the circuit training group and the control group or the isometric exercise group and the control group.

The within group comparison showed that all groups improved in mean treadmill performance time at the .01 level of confidence.

There was no observable difference between mean heart rate times and oxygen consumption values either before exercise or during recovery from the exercise. There was no change as a result of the five weeks of training nor was there any difference between groups.

Conclusions

Within the limitations of the study the following conclusions are made.

1. Circuit training causes a significantly greater improvement in treadmill performance time, as measured by the Balke treadmill test, than do isometric exercises.

2. Three ten minute periods of circuit training per week or three ten minute periods of isometric exercises per week in addition to badminton, for five weeks are no more effective in improving treadmill performance time than two periods of badminton per week for five weeks.

3. Pre-exercise heart rate and pre-exercise oxygen consumption are not altered by three ten minute periods of

circuit training per week for five weeks or by three ten minute periods of isometric exercises per week for five weeks.

4. Heart rate during five minutes of recovery from treadmill walking or oxygen consumption during three minutes of recovery from the same exercise are not affected by circuit training or by isometric exercises done three times per week for ten minutes for five weeks.

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APPENDIX A

STATISTICAL TREATMENT

The data were treated statistically by the analysis of variance method. Results were accepted as significant at the 5 percent level of confidence.

Reliability of the test. Reliability coefficients, obtained by use of Pearson's correlation coefficient (1:258), were computed from the test-retest results of the subjects tested on the first two days of testing. The following formulae were used:

$$r = \frac{Sxy}{Sx\,Sy} \quad \text{where} \quad Sx^2 = \frac{N\Sigma x^2 - (\Sigma x)^2}{(N)^2}$$

$$\text{and} \quad Sy^2 = \frac{N\Sigma y^2 - (\Sigma y)^2}{(N)^2}$$

$$\text{and} \quad Sxy = \frac{N(\Sigma xy) - (\Sigma x \Sigma y)}{(N)^2}$$

Procedure. After the second test on the treadmill was given the subjects were equated on the basis of their treadmill performance times into three groups of fifteen subjects each (2:337). Each of these groups were selected randomly for one of the three treatments, either control, circuit training or isometric exercises.

Difference in Mean Performance. The null hypothesis was tested by the method outlined by Garrett (3:270).

Individual scores of the times on the last treadmill performance test were listed under the three headings which designate the conditions under which the groups trained before the final test was given. "Since conditions furnished the category for the assignment of subjects, in the terminology of analysis of variance there was said to be one criterion of classification" (3:281).

> The first step in our analysis is a breakdown of the total variance (6^2) of the 45 scores into two parts: (1) the variance attributable to the different condition, or the variance among the three means, and (2) the variance arising from individual differences within the 3 groups. The next step is to determine whether the group means differ significantly _inter se_ in view of the variability within the separate groups (individual differences).

Step 1. Correction term (c).

$$C = \frac{(\Sigma X)^2}{N}$$

Step 2. Total sum of squares around the general mean.

$$SS_t = \Sigma X^2 - C$$

Step 3. Sum of squares among the means obtained under the 3 conditions.

$$SS \text{ (among means)} = \frac{(\Sigma X_1)^2}{n_1} + \frac{(\Sigma X_2)^2}{n_2} + \frac{(\Sigma X_3)^2}{n_3} - C$$

Step 4. Sum of squares within conditions (individual differences).

$$SS_w = SS_t - SS_{m's}$$

Step 5. Calculation of the variances from each SS and analysis of the total variance into its components was done in table form. Each SS became a variance when divided by the degrees of freedom (df)

allotted to it (3:194). The degrees of freedom (df) for among the means of conditions and (df) for within groups or within conditions was determined.

Step 6. In the problem the null hypothesis asserts that the means of the three conditions A,B, and C will differ only through fluctuations of sampling. To test this hypothesis the among means variance was divided by the within groups variance and the resulting variance ratio, called F, was compared with the F values in Table F (2:451).

> F furnishes a comprehensive or over-all test of the significance of the differences among means. A significant F does not tell us which means differ significantly, but that at least one is reliably different from some others. If F is not significant, there is no reason for further testing, as none of the means differences will be significant. But if F is significant, we may proceed to test the separate differences by the t test (2:191).

The treadmill performance times on the final test were analysed in the method outlined above. The oxygen consumption determinations and the recovery rate determinations made through-out the study were plotted on graphs.

Initial and final score analysis. The significance of the difference between means obtained an initial and final test days was determined by the method outlined by Garrett (2:228).

The formula involved in the "t-test" were as follows:

$$SD = \sqrt{\frac{x^2}{N-1}}$$

$$SD_M = \frac{SD}{\sqrt{N}}$$

$$SE_D = \sqrt{(SD_{M_1})^2 + (SD_{M_2})^2 - 2r_{12} \times SD_{M_1} . SD_{M_2}}$$

where

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \times \Sigma y^2}}$$

$$t = \frac{M_1 - M_2}{SE_D}$$

The method outlined above was also used to analyse the differences between groups after differences were found to exist by the analysis of variance method.

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APPENDIX B

Circuit Training Program Plan Form

Item	Circuit I	Circuit II	Circuit III	Circuit IV	Circuit V
			Number of Repetitions		
1. Squat Jumps	15	22	25	28	30
2. Chinning	3	3	4	5	6
3. Sit-ups	10	15	17	19	20
4. Squat Thrusts	12	15	17	19	21
5. Wrist Rolling	4	6	7	8	9
6. Push-ups	5	7	8	9	10
7. Step-ups	15	20	23	26	30
8. Pull-over	2	2	3	4	5

Time 10 minutes.

APPENDIX C

AGE AND WEIGHT OF SUBJECTS

IN EACH GROUP

CIRCUIT TRAINING GROUP

Subject		Age (yrs.)	Weight (kgs.)
1		18	65.9
2		18	64.5
3		17	75.0
4		17	65.9
5		19	66.8
6		25	61.4
7		18	50.0
8		20	76.8
9		18	77.3
10		18	76.8
11		18	62.7
N= 11	Sum	206	743.1
	Mean	18.7	67.6
	Standard Deviation	2.1	8.0

ISOMETRIC EXERCISE GROUP

Subject		Age (yrs.)	Weight (kgs.)
1		17	77.3
2		19	66.4
3		18	80.0
4		18	65.5
5		19	79.5
6		18	76.8
7		20	67.3
8		19	97.3
9		19	65.5
10		17	63.6
11		20	65.9
N= 11	Sum	204	805.1
	Mean	18.5	73.2
	Standard Deviation	1.0	9.8

CONTROL GROUP

Subject		Age (yrs.)	Weight (kgs.)
1		18	75.5
2		20	67.3
3		18	81.8
4		18	63.6
5		18	81.8
6		20	68.6
7		18	74.5
8		21	59.1
9		18	70.5
10		19	85.9
11		19	63.6
N = 11	Sum	207	792.2
	Mean	18.8	72.0
	Standard Deviation	1.0	8.3

TREADMILL PERFORMANCE TIMES
(in minutes)

SUBJECT	GROUP I Initial Test	GROUP I Final Test	GROUP II Initial Test	GROUP II Final Test	GROUP III Initial Test	GROUP III Final Test
1	19	23	18.5	21	18.5	18.5
2	16.5	20.5	17	17	17.5	18
3	15.5	16.5	15.5	18	15.5	18.5
4	15.5	16	15.5	17	15.5	18.5
5	15.5	17.5	15.5	15.5	15	18.5
6	14	19.5	14	17	14	17
7	14	16.5	13.5	13	13.5	14
8	13	15	13	13	13	13.5
9	12.5	18	12	14	12	13.5
10	12	16.5	11.5	12	11.5	13.5
11	10	11	11	13.5	11	12.5
N = 11 Sum	157.5	190.0	157.0	171.0	157.0	176.0
Mean	14.32	17.27	14.27	15.55	14.27	16.00
S.D.	2.45	3.11	2.36	2.72	2.40	2.55

Group I - Circuit Training Group
Group II - Isometric Exercise Group
Group III - Control Group

HEART RATE DURING REST AND RECOVERY

FROM EXERCISE FOR THE CIRCUIT TRAINING GROUP
(Pulse Rate Per Min.)

Subject	TRIAL I Rest	TRIAL I Recovery (In Min.)					TRIAL II Rest	TRIAL II Recovery (In Min.)					TRIAL III Rest	TRIAL III Recovery (In Min.)				
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
1	105	136	132	125	125	110	94	132	118	113	100	98	90	127	114	114	109	103
2	58	129	113	103	103	110	60	136	129	118	118	113	80	140	120	117	114	112
3	90	132	118	113	113	110	85	125	115	113	100	107	90	140	127	124	127	120
4	80	129	115	105	110	100	66	118	110	107	110	87	72	120	114	105	92	98
5	83	136	125	122	118	113	88	141	118	118	122	113	80	144	130	124	120	120
6	92	136	110	105	113	100	100	136	125	122	113	105	80	140	114	109	114	98
7	78	141	125	118	113	118	90	141	122	113	113	113	73	135	117	112	112	109
8	80	141	122	118	122	113	96	136	129	122	113	105	72	144	124	120	112	112
9	100	X	X	X	X	X	100	129	125	122	122	115	88	144	120	117	117	112
10	90	118	115	105	103	103	63	113	107	96	79	110	87	117	90	96	105	88
11	98	150	136	136	122	122	79	136	122	115	113	105	105	135	120	117	103	117
N = 1																		
SUM =	954	1348	1211	1150	1142	1099	921	1443	1320	1259	1203	1171	917	1486	1290	1255	1224	1189
MEAN =	87	135	121	115	114	110	84	131	120	114	109	106	83	135	117	114	111	108

HEART RATE DURING REST AND RECOVERY

FROM EXERCISE FOR THE ISOMETRIC EXERCISE GROUP
(Pulse Rate Per Min.)

Subject	TRIAL I Rest	TRIAL I Recovery (In Min.)					TRIAL II Rest	TRIAL II Recovery (In Min.)					TRIAL III Rest	TRIAL III Recovery (In Min.)				
	0	1	2.	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
1	87	136	118	115	105	100	90	129	110	110	100	96	90	130	109	100	105	X
2	78	141	141	136	115	105	70	125	115	105	107	100	77	135	124	120	109	105
3	79	122	115	115	107	100	69	115	90	105	100	105	88	120	112	103	103	100
4	110	125	129	118	113	107	110	132	129	125	118	X	87	127	120	120	114	114
5	83	145	132	129	122	115	83	129	125	122	122	105	99	138	129	122	122	118
6	98	132	132	125	115	113	82	129	120	122	113	100	87	130	127	117	105	100
7	103	150	145	129	125	103	92	141	125	125	115	115	94	144	130	127	127	120
8	90	136	125	115	X	115	75	129	100	105	105	105	94	138	112	109	109	109
9	94	141	118	115	122	110	110	141	118	115	125	115	88	140	130	114	105	114
10	87	129	118	122	105	105	90	125	113	105	105	98	80	140	120	117	103	105
11	100	141	136	122	113	113	94	155	125	118	115	110	87	149	130	120	124	105
N = 11																		
SUM =	1009	1488	1409	1341	1142	1185	965	1450	1270	1257	1225	1049	971	1491	1343	1269	1226	1090
MEAN =	92	135	128	122	114	108	88	132	115	114	111	105	88	136	122	115	111	109

HEART RATE DURING REST AND RECOVERY

FOR EXERCISE FOR THE CONTROL GROUP
(Pulse Rate Per Min.)

Subject	TRIAL I						TRIAL II						TRIAL III					
	Rest	Recovery (In Min.)					Rest	Recovery (In Min.)					Rest	Recovery (In Min.)				
	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
1	82	141	122	107	115	105	105	145	122	113	115	118	90	140	120	127	120	117
2	65	110	105	107	107	X	88	132	113	110	113	103	85	127	114	109	112	105
3	105	141	125	113	110	110	90	141	122	115	107	107	80	140	120	114	112	105
4	96	132	118	115	107	104	105	136	122	113	110	105	82	130	120	114	103	105
5	82	129	118	129	115	113	71	118	107	100	94	107	71	120	109	98	105	105
6	96	150	132	125	129	125	96	136	129	129	122	113	100	144	127	114	112	109
7	98	141	141	141	115	125	118	136	132	141	90	115	100	144	130	127	140	120
8	83	136	X	118	113	105	79	132	129	122	118	113	90	140	127	120	120	113
9	140	150	145	136	132	136	107	141	136	129	129	125	114	144	135	135	127	127
10	98	141	129	118	122	113	90	150	132	122	118	118	98	149	135	130	120	120
11	94	141	136	141	X	X	88	145	141	145	115	122	88	144	124	127	112	98
N = 11																		
SUM =	1039	1512	1271	1350	1165	1036	1037	1512	1385	1339	1211	1246	998	1522	1361	1315	1283	1224
MEAN =	94	137	127	123	117	115	94	137	126	122	110	1·13	91	138	124	120	116	111

OXYGEN CONSUMPTION AT REST AND DURING RECOVERY FROM EXERCISE FOR THE CIRCUIT TRAINING GROUP ON INITIAL AND FINAL TEST DAYS

TRIAL II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	c.c./min	c.c./min	c.c./min	c.c./min
1	376	1789	653	474
2	462	1820	653	515
3	415	2043	788	568
4	309	1657	693	517
5	306	1658	742	567
6	442	1867	726	467
7	379	1193	556	360
8	312	1593	690	482
9	495	1751	769	579
10	491	1750	1197	X
11	367	1537	634	579
Sum	4354	18658	8101	5108
Mean	396	1696	736	511

TRIAL III				
1	358	1789	842	585
2	278	2198	1201	583
3	X	2226	906	644
4	303	1756	704	578
5	324	1754	762	542
6	376	2287	989	685
7	259	1333	538	407
8	304	1798	899	699
9	214	1839	1030	692
10	513	2030	902	495
11	389	1335	618	486
Sum	3318	20345	9391	6396
Mean	302	1850	854	581

OXYGEN CONSUMPTION AT REST AND DURING RECOVERY FROM EXERCISE FOR THE ISOMETRIC EXERCISE GROUP ON INITIAL AND FINAL TEST DAYS

TRIAL II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	c.c./min	c.c./min	c.c./min	c.c./min
1	450	2289	992	710
2	409	1758	752	486
3	410	2071	714	430
4	491	1793	626	510
5	425	1900	895	558
6	395	1840	695	441
7	373	2295	893	609
8	338	2180	874	624
9	325	1650	790	560
10	340	1053	548	422
11	344	1240	674	479
Sum	4300	18276	8453	5829
Mean	391	1661	768	530

TRIAL III				
1	406	2301	1077	739
2	374	1739	801	399
3	397	1891	775	605
4	303	1914	847	568
5	452	1514	597	X
6	372	1913	830	534
7	X	1633	533	450
8	445	2167	856	634
9	365	1658	794	563
10	313	1503	652	405
11	323	1656	848	739
Sum	3750	19889	8610	5636
Mean	375	1808	783	512

OXYGEN CONSUMPTION AT REST AND DURING RECOVERY FROM EXERCISE FOR THE CONTROL GROUP ON INITIAL AND FINAL TEST DAYS

TRIAL II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	c.c./min	c.c./min	c.c./min	c.c./min
1.	454	2544	1043	768
2	448	2533	1051	751
3	404	2217	1042	654
4	445	1632	830	657
5	365	1882	463	549
6	447	1724	592	451
7	440	1957	833	604
8	391	1551	719	413
9	362	1456	715	571
10	445	2172	928	651
11	405	1514	744	528
Sum	4606	21182	8900	6597
Mean	419	1926	815	600

TRIAL III				
1	406	2267	940	742
2	539	2245	1175	660
3	344	1899	1048	658
4	362	2167	897	656
5	296	2160	1206	1170
6	379	2054	928	659
7	399	1431	703	637
8	344	1656	548	389
9	406	1587	757	611
10	X	2075	1108	799
11	467	1503	710	623
Sum	3942	21044	10020	7604
Mean	394	1913	911	691

MINUTE VOLUME OF LUNG VENTILATION AND VENTILATORY EQUIVALENT

BEFORE EXERCISE AND DURING RECOVERY FOR THE

INITIAL AND FINAL TESTS OF THE CIRCUIT TRAINING GROUP

TEST II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	Min. Vol. lit./min.	Min. Vol lit./min	Min. Vol lit./min	Min. Vol lit./min
1	8.91	33.14	17.24	12.87
2	11.23	37.37	18.35	13.24
3	11.98	42.22	20.86	14.63
4	7.74	31.45	16.90	14.04
5	8.44	37.94	21.13	16.14
6	15.21	44.25	26.98	17.77
7	8.93	22.50	13.11	8.29
8	8.15	32.45	18.55	13.73
9	11.96	35.74	19.63	15.19
10	12.81	34.86	32.17	X
11	9.39	32.99	15.40	15.23
Sum	114.75	384.91	220.32	141.13
Mean	10.43	34.99	20.03	14.11

TEST III				
1	11.18	37.29	21.95	16.67
2	7.56	48.42	33.63	16.85
3	X	44.43	22.38	15.48
4	7.28	38.35	18.93	15.55
5	7.60	41.17	21.04	14.11
6	11.04	48.56	27.24	22.17
7	6.05	24.87	11.42	9.76
8	8.12	40.95	23.35	18.70
9	9.01	42.57	26.48	18.86
10	13.79	42.21	25.77	13.30
11	7.64	26.23	16.26	12.42
Sum	89.27	435.05	259.87	173.87
Mean	8.93	39.55	23.62	15.81

MINUTE VOLUME OF LUNG VENTILATION AND VENTILATION EQUIVALENT

BEFORE EXERCISE AND DURING RECOVERY FOR THE

INITIAL AND FINAL TESTS OF THE ISOMETRIC EXERCISE GROUP

TEST II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	Min. Vol. lit./min	Min. Vol lit./min	Min. Vol lit./min	Min. Vol lit./min
1	11.48	41.25	22.80	17.61
2	9.77	38.14	18.94	11.91
3	11.52	48.16	19.50	12.08
4	14.71	44.93	19.39	15.26
5	13.31	37.11	25.54	20.22
6	8.64	36.75	18.79	11.91
7	11.97	40.99	27.64	20.16
8	11.72	55.18	22.69	16.95
9	7.33	35.87	21.12	17.42
10	13.09	33.55	14.50	12.59
11	7.81	30.38	19.58	13.50
Sum	121.35	442.31	230.49	169.61
Mean	11.03	40.21	20.91	15.42

TEST III				
1	8.74	44.43	26.21	17.97
2	8.55	38.82	26.18	13.05
3	11.69	40.33	20.82	16.71
4	12.73	49.08	20.56	16.91
5	14.87	32.28	14.96	X
6	10.88	44.91	23.65	16.13
7	X	35.04	15.90	13.79
8	12.51	46.81	22.05	17.24
9	7.75	36.04	21.22	16.00
10	9.29	32.96	18.74	12.41
11	7.98	35.31	22.80	20.41
Sum	104.99	436.01	233.09	160.62
Mean	10.50	39.64	21.19	16.06

MINUTE VOLUME OF LUNG VENTILATION AND VENTILATION EQUIVALENT

BEFORE EXERCISE AND DURING RECOVERY FOR THE

INITIAL AND FINAL TESTS OF THE CONTROL GROUP

TEST II	PRE-EXERCISE	RECOVERY (IN MIN.)		
		1	2	3
Subject	Min. Vol. lit./min	Min. Vol lit./min	Min. Vol lit./min	Min. Vol lit./min
1	12.27	61.59	32.91	21.32
2	14.76	62.86	32.15	23.69
3	9.21	44.07	24.98	17.49
4	14.27	43.87	25.69	21.77
5	10.55	38.10	18.00	15.39
6	11.12	38.75	17.51	12.52
7	9.51	37.86	26.69	16.51
8	12.74	35.65	24.28	15.65
9	8.20	28.43	17.91	15.56
10	11.43	40.98	26.06	15.84
11	12.50	31.28	24.48	19.47
Sum	126.56	463.44	270.66	195.21
Mean	11.51	42.13	24.61	17.75

TEST III				
1	10.61	49.39	28.66	21.89
2	14.76	46.39	30.43	16.62
3	7.66	42.30	25.13	17.60
4	12.19	58.24	29.12	21.30
5	7.70	50.42	28.93	31.30
6	7.16	45.25	26.06	18.52
7	9.58	27.26	14.62	14.95
8	12.41	36.01	19.03	13.02
9	10.59	29.72	20.36	17.98
10	X	48.48	33.59	23.43
11	12.19	30.62	20.22	20.22
Sum	104.85	464.08	276.15	216.83
Mean	10.49	42.19	25.10	19.71